

New trends
in biology teaching

Tendances nouvelles
de l'enseignement
de la biologie

Volume II

With summaries in Spanish
Avec des résumés en espagnol

The teaching of basic sciences
L'enseignement des sciences fondamentales

Biology
Biologie

Unesco



The teaching of basic sciences

L'enseignement des sciences fondamentales

1

New trends in biology teaching

Tendances nouvelles de l'enseignement de la biologie

Vol. II

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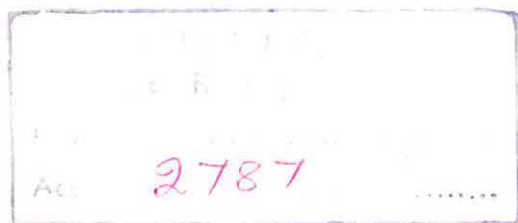
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P R E F A C E

Promotion of the exchange of information on the content and methodology of science teaching forms an important part of Unesco's programme to develop and improve science education at all levels. To this end, Unesco is publishing, within the collection *The Teaching of Basic Sciences*, a series of volumes entitled *New Trends in . . .*, which consist of papers and articles from leading science-teaching journals on content, curricula, approaches and techniques in the teaching of the three basic sciences - physics, chemistry and biology - and mathematics.

The four volumes published in 1967-68 represented a first experiment to find the best means of placing useful information on basic science teaching in the hands of as many science educators as possible at minimum cost and delay. Although the volumes were intended mainly for teachers in universities and teacher-training institutions, experience has shown that they can also help secondary-school teachers in their difficult task of keeping abreast of the rapid developments taking place in curricula, syllabuses, methods and materials for science teaching, as well as university students of biology who are training to be teachers. Science educators in national science teachers' associations, in ministries of education and on examination boards are also likely to find the information helpful.

This second volume on *New Trends in Biology Teaching* presents papers originally published during 1966 and 1967 in leading biology teaching periodicals of the world, as well as articles written specially for it, keeping in mind the need to achieve a wide representation. Unesco asks for the continued help of readers in assuring an even more international character for subsequent volumes. It gratefully acknowledges the readiness with which editors and publishers of journals have given permission for the reproduction of papers.

To simplify the use of this volume, the papers have been grouped in sections: the first section deals with general topics; the second with individual disciplines; the third with educational methods and techniques; and the fourth with local developments. This grouping should facilitate the task of introducing new topics into the biology syllabus as well as that of bringing subject matter up to date.

This volume has been prepared in close collaboration with the Commission on Higher Education in Biology of the International Union of Biological Sciences, namely professors P. Chouard, R. Heller (France), R. A. Kille (United Kingdom), N. Lindauer (Federal Republic of Germany), D. M. Reynolds (United States of America) and F. Sladeček (Czechoslovakia). Professor R. Heller, who is the Executive Secretary of the commission, has kindly acted as co-ordinator.

The choice of papers and articles, their presentation and the opinions expressed in them are the responsibility of the editor and the authors.

P R É F A C E

L'action en faveur des échanges d'informations sur le contenu et les méthodes de l'enseignement des sciences constitue une partie importante du programme qu'applique l'Unesco pour développer et améliorer cet enseignement à tous les niveaux. A cette fin l'Unesco publie, dans la collection «L'enseignement des sciences fondamentales», une série de volumes intitulés *Tendances nouvelles* . . . , qui contiennent des études et des articles extraits des principales revues pédagogiques spécialisées et consacrées au contenu, aux programmes, à la conception générale et aux techniques de l'enseignement des trois sciences fondamentales - la physique, la chimie et la biologie - ainsi que des mathématiques.

Les quatre volumes publiés en 1967-1968 constituent une première expérience qui vise à trouver le meilleur moyen de mettre des renseignements utiles sur l'enseignement des sciences fondamentales à la disposition du plus grand nombre possible de professeurs de sciences, au moindre coût et dans les plus brefs délais. Ces volumes s'adressaient surtout aux professeurs d'université ou d'école normale; mais on a constaté qu'ils peuvent aussi aider les professeurs du second degré dans cette tâche difficile consistant à suivre l'évolution rapide qui se produit en matière de plans d'études, de programmes, de méthodes et de matériel relatifs à l'enseignement des sciences, et servir aux étudiants en biologie qui se destinent au professorat. En outre, les professeurs de sciences qui appartiennent à des associations nationales d'enseignants, travaillent dans des ministères de l'éducation ou sont membres de jurys d'examen, y trouveront probablement d'utiles informations.

Dans ce second volume consacré aux *Tendances nouvelles de l'enseignement de la biologie*, on a réuni des études publiées initialement en 1966 et en 1967 dans les principaux périodiques du monde concernant l'enseignement de la biologie, ainsi que des articles originaux, en veillant à la nécessité d'une large représentativité. L'Unesco demande aux lecteurs de continuer à l'aider à donner un caractère encore plus international aux prochains volumes. Elle exprime sa vive reconnaissance aux directeurs et éditeurs de périodiques qui ont bien voulu autoriser la reproduction d'articles extraits de leurs publications.

Pour que le présent volume soit d'un emploi plus commode, on a groupé les articles en plusieurs parties: la première est consacrée à des sujets généraux, la deuxième à des disciplines particulières, la troisième aux méthodes et techniques pédagogiques et la quatrième aux réalisations locales. Ce classement devrait faciliter l'inclusion de nouveaux sujets dans le programme de biologie, ainsi que la mise à jour des questions.

Ce volume a été établi en étroite collaboration avec la Commission de l'enseignement supérieur de la biologie, de l'Union internationale des sciences biologiques, c'est-à-dire avec les professeurs P. Chouard, R. Heller (France), R.A. Kille (Royaume-Uni), N. Lindauer (République fédérale d'Allemagne), D.M. Reynolds (Etats-Unis d'Amérique) et F. Sladěček (Tchécoslovaquie). Le professeur R. Heller, secrétaire exécutif de la commission, a bien voulu se charger des fonctions de coordonnateur.

Le directeur de la publication et les auteurs sont responsables du choix des études et des articles, de leur présentation et des opinions qui y sont exprimées.

INTRODUCTION

The reception received by the first volume of *New Trends in Biology Teaching* has encouraged Unesco and the Commission on Education of the International Union of Biological Sciences to publish a second on the same line's.

The aims have not changed. As the minimum an educated man requires to know expands in geometrical progression and scientific discoveries are incorporated into daily life with ever-increasing rapidity, teaching methods must evidently be adapted accordingly, without prejudice, of course, to the individual abilities of teachers, which remain the vital element of success in teaching.

In biology, the amount that students must be taught is staggering. They must learn to know themselves, study man, his organs and their functions. They must be given an intelligent grip on the world around them: living creatures, their forms and behaviour, reproduction and evolution, the implications for agriculture, livestock, fisheries, industry - these are the traditional and still most fundamental aspects of biology teaching. But it would be contrary to the educational purpose of such teaching to be satisfied with a purely external description of phenomena without making some attempt at least at analysing their mechanisms. Despite their increasing reliance on the underlying sciences - mathematics, physics and chemistry - developments in the modern branches (animal and plant physiology, biochemistry, genetics, molecular biology) cannot remain wholly unknown to students in our secondary schools.

To help biology teachers in their difficult job, a selection was made, as varied as possible, from articles by experts from various countries, and arranged under four main headings.

The first section is very general - principles of biology teaching, purpose, implications in everyday life, social responsibilities of its teachers. The second is concerned with individual disciplines (particularly if there are teaching difficulties) - new branches such as biochemistry or cybernetics, and more traditional subjects such as taxonomy or systematics, which are not easy to teach interestingly while remaining educative. Several articles are then devoted to methods and techniques. They provide hints and suggestions regarding practicals in class- and field-work, teaching models, audio-visual aids, films, new prospects in programmed education, and even - a particularly delicate subject - examinations and tests. As in the first volume, critical studies of some successful modern biology-teaching experiments provide food for thought and suggest experiments.

The documentary section at the end includes a list of addresses of educational associations and institutes which can supply teachers with equipment or information on request.

In comparison with the first volume, it will be seen that this one is better produced. The first was a rushed job. Without being extravagant, we have tried to make this more attractive and easier to consult. Moreover, an editorial committee consisting of Miss R. John (Unesco) and professors F. Sladeček and N. Lindauer, Dr. R. A. Kille and Professor R. Heller (International Union of Biological Sciences) was able to meet and make a final and more homogeneous selection of articles.

The chief difficulty is still, as with the first volume, the variety of what was received, coming from countries and outlooks that are as different as could be, and dealing with the

most diverse subjects. The documentation section, too, is less rich than we could have liked. Since we must already be thinking about the next volume, we accordingly can only appeal again to all interested in biology teaching to let us have their suggestions and their criticisms.

Biology, of all the disciplines, is the one that most directly affects human well-being. To facilitate its progress and improve the student's grasp is not only a work of education but a positive step towards improving man's lot generally.

R. Heller
Professor of Plant Physiology,
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PS. Manuscripts for the next volume, written in English, French or Spanish and accompanied by a 10- to 20-line summary, should be forwarded in duplicate to one of the persons whose names appear below. We are extremely anxious to receive information - however brief - regarding existing institutes or associations concerned with biology teaching, so as to enhance the documentary value of the publication.

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INTRODUCTION

L'audience rencontrée par le premier volume des *Tendances nouvelles de l'enseignement de la biologie* a incité les autorités de l'Unesco et les membres de la Commission de l'enseignement de l'Union internationale des sciences biologiques à éditer un deuxième recueil dans le même esprit.

Les objectifs n'ont pas changé. A l'heure où les connaissances nécessaires à l'homme cultivé d'aujourd'hui se développent à une allure exponentielle et où l'intégration des découvertes scientifiques à la vie quotidienne devient de plus en plus rapide, la nécessité d'une adaptation des méthodes pédagogiques se révèle de plus en plus impérieuse, sans vouloir supplanter les qualités personnelles des maîtres, qui restent le facteur essentiel du succès.

En biologie, la masse des connaissances à inculquer aux élèves est impressionnante. Il faut d'abord leur apprendre à se connaître eux-mêmes, leur faire étudier l'homme, ses principaux organes et leurs fonctions. Il faut aussi leur offrir une prise de contact intelligente avec le monde qui les entoure : la connaissance des formes et du comportement des êtres vivants, de leur mode de reproduction et de leur évolution – sans oublier les incidences impliquées sur l'agriculture, l'élevage, la pêche ou l'industrie – restent les aspects les plus traditionnels et les plus fondamentaux de l'enseignement de la biologie. Toutefois, il serait contraire à la vocation culturelle de cet enseignement de se cantonner dans une description purement extérieure des phénomènes sans une analyse, au moins approchée, de leurs mécanismes. Le développement des branches modernes – physiologie animale et végétale, biochimie, génétique, biologie moléculaire – ne peut, dans ses grandes lignes, être ignoré des élèves de nos établissements secondaires, malgré l'appel de plus en plus important qu'elles font aux sciences-supports : mathématiques, physique et chimie.

C'est pour aider à la résolution des difficiles problèmes qui se posent aux professeurs de biologie qu'un choix fut fait, aussi varié que possible, d'un certain nombre d'articles écrits par des spécialistes de différents pays. Ils furent groupés en quatre rubriques principales.

Une première partie très générale, traite des principes qui doivent régir l'enseignement de la biologie, de sa finalité, de ses implications dans la vie quotidienne et des responsabilités sociales qui s'attachent à ceux qui l'enseignent. Une deuxième partie s'arrête sur des disciplines particulières, principalement sur celles qui soulèvent des difficultés pédagogiques, qu'il s'agisse de branches nouvelles comme la biochimie ou la cybernétique, ou de matières plus traditionnelles, comme la taxonomie ou la systématique dont l'enseignement n'est pas aisé, s'il veut rester intéressant et garder une valeur éducative. Plusieurs articles sont ensuite consacrés aux méthodes et aux techniques : on y trouvera des indications et des suggestions pour les travaux pratiques, dans la classe et sur le terrain, pour l'utilisation de modèles pédagogiques, ainsi que sur l'emploi des techniques audio-visuelles et des films avec des perspectives nouvelles sur l'enseignement programmé et même, sujet particulièrement délicat, sur le problème des examens et le contrôle des connaissances. Enfin, comme

dans le premier tome, des études critiques sur des réalisations effectives dans le sens d'un enseignement moderne de la biologie seront matière à réflexion et suggéreront des expériences.

Le volume s'achève par une partie documentaire donnant notamment les adresses d'un certain nombre d'associations et d'institutions pédagogiques susceptibles de fournir du matériel ou de répondre à des demandes de renseignements de la part des maîtres.

Par rapport au premier volume pour lequel nous avons été obligé de faire vite, l'ouvrage que nous présentons aujourd'hui se distinguera d'abord par une présentation plus soignée. Sans recourir à des procédés trop coûteux, nous avons tenté de lui donner un aspect plus agréable et plus facile à consulter. D'autre part un comité de rédaction composé de Mlle John (Unesco), du professeur Sladeček, du professeur Lindauer, du Dr Kille et du professeur Heller (Union internationale des sciences biologiques) a pu se réunir pour le choix définitif des articles et aboutir à une sélection plus homogène.

Il reste que la principale difficulté à laquelle nous nous heurtons demeure, comme pour le premier volume, celle d'une documentation variée. venant des pays et des horizons les plus différents, et traitant des sujets les plus divers. La section de documentation est, elle aussi, moins riche que nous ne l'aurions voulu. C'est dire que, puisqu'il faut déjà songer à la préparation du prochain volume, nous ne pouvons que renouveler notre appel pour que tous ceux qui s'intéressent à l'enseignement de la biologie nous fassent part de leurs suggestions et de leurs critiques.

La biologie est, de toutes les disciplines, l'une de celles qui est le plus directement en rapport avec le bien-être humain. En facilitant son développement, en la faisant mieux connaître des élèves, on n'accomplit pas seulement une tâche d'éducateur, on œuvre pour l'épanouissement d'un meilleur destin des hommes.

R. Heller

Professeur de physiologie végétale
à la Faculté des sciences de Paris

Note: Les manuscrits pour le prochain volume sont à adresser (en double exemplaire, rédigés en anglais, en espagnol ou en français, et précédés d'un résumé de 10 à 20 lignes), à l'une des personnalités suivantes. Nous attachons beaucoup de prix à recevoir des indications, même succinctes, sur les institutions ou associations existantes, qui s'intéressent à l'enseignement de la biologie, de manière à amplifier le caractère documentaire de cet ouvrage.

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Section 1/Partie 1

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GENERAL / SUJETS GENERAUX

En même temps qu'elle nous
révèle la particularité de
chacun, la biologie nous
rappelle la fraternité de tous.

Jean Rostand

Vers un enseignement nouveau de la biologie

Par PAUL-EMILE PILET

1. *Avant-propos*

En quelque vingt ans, la *biologie* a fait un bond considérable en avant. Si les problèmes que cette science a pour but de préciser ne sont pas fondamentalement différents de ceux que LAMARCK envisageait, en 1809, lorsqu'il proposait d'appeler biologie la *science de la vie et des vivants*, les méthodes, elles, ont fort varié. Et avec les méthodes, le but même de la biologie a changé; il est en effet loin d'être ce qu'il était à la fin du siècle passé. Aujourd'hui, la biologie est nettement «explicative» alors qu'il y a à peine trente ans, elle était essentiellement «descriptive».

Mais ce nouveau visage de la biologie n'est-il que pour les spécialistes, c'est-à-dire pour ceux qui l'ont, en quelque sorte, façonnée et qui ont pris part, plus ou moins activement, à sa structuration moderne? Peut-on décemment continuer à enseigner la biologie traditionnelle à l'Université et dans nos écoles dites «secondaires» surtout sans se préoccuper de ce qu'est réellement la biologie de notre temps?

Nous l'avons dit, les données biologiques ont été très profondément remaniées ces dernières années. Pour donner de la vie et des vivants une vision conforme aux acquisitions récentes, nous ne pouvons plus aujourd'hui nous borner à intégrer quelques notions nouvelles aux chapitres types de la biologie classique. Il n'est donc plus possible – comme cela pouvait se faire, il y a quinze ans encore – d'incorporer, sans plus, certains faits nouveaux et ceci sans modifier l'enseignement de base. C'est donc vers une restructuration totale de la biologie que nous allons et forcément vers une révision complète de toutes les matières enseignées.

Il faut bien l'admettre, la biologie est une branche de culture générale et son enseignement – à quelque niveau que ce soit – s'adresse à des auditeurs qui plus tard ne seront pas, pour la plupart, des biologistes. A ce «public», étudiants ou lycéens, ne convient-il pas de donner de la science de la vie une

image véridique et dynamique? N'est-il pas urgent de renoncer aux notions souvent périmées, qui encombrant les programmes, d'une «histoire naturelle» traditionnelle? N'est-il point indispensable de présenter quelques-unes des données les plus remarquables de la biologie moderne? Ce faisant, l'enseignement jouera réellement le rôle qu'on lui demande; il ne sera pas – comme c'est malheureusement encore parfois le cas – le «repoussoir» de vocation, mais au contraire entraînera des indécis vers les sciences biologiques. Ne voit-on pas communément aujourd'hui des jeunes gens passionnés de problèmes relatifs à la vie, mais qu'une taxonomie prématurément et abusivement enseignée écarte à tout jamais de la biologie expérimentale.

Sans doute n'est-il pas toujours possible de «vulgariser» les questions essentielles d'un enseignement adapté. C'est là un problème fondamental et délicat; nous en reparlerons plus loin. Cependant, tout en réformant les matières du programme, il convient de dire d'emblée que ce qui importe aussi, c'est que l'esprit dans lequel elles devraient être enseignées soit repensé.

Qu'on le veuille ou non, il y a actuellement un malaise au niveau de ceux qui ont la charge d'enseigner la biologie, que ce soit à un auditoire de lycéens des classes supérieures ou à des étudiants de première et de seconde année (cycle propédeutique).

Dans un certain nombre de pays, des enquêtes ont été envisagées; certaines ont permis de mettre au point des enseignements pilotes. A titre d'exemple, citons l'énorme travail entrepris, en Angleterre, par la *Fondation Nuffield* [1]¹⁾, institution d'assistance privée qui procède, depuis quelques années déjà, à une révision des programmes de l'enseignement scientifique et notamment de la biologie. Depuis 1962, cette fondation a mis en application des programmes nouveaux; des essais, systématiquement contrôlés, sont en cours, auxquels prennent part 49 écoles pour la physique, 56 pour la chimie et . . . 66 pour la biologie. Il est question que ce nouveau programme soit adopté par une forte proportion des écoles britanniques, à la fin de 1966 [2]. Il faut bien reconnaître qu'à cet égard l'Angleterre est fort en avance sur les autres pays d'Europe; l'article de notre collègue et ami, le professeur H. E. STREET – publié ici-même [3] – le prouve éloquemment.

Il convient aussi de mentionner, dans le même ordre d'idée, le Colloque international organisé par l'O.C.D.E. à la Tour-de-Peilz, en septembre 1962. Au cours de ce colloque, des personnalités de plus de vingt pays se penchèrent sur les problèmes que pose l'enseignement actuel de la biologie. Les exposés présentés ont été réunis dans un volume de près de 350 pages dont le titre rappelle bien les intentions des organisateurs: «Pour un nouvel enseignement de la biologie» [4].

¹⁾ Les chiffres entre crochets renvoient à la bibliographie, pages 282 à 283.

2. La biologie d'aujourd'hui

Sans vouloir discuter ici les divers aspects de la biologie actuelle [5], examinons très brièvement l'essentiel de ses tendances.

Il est évidemment nécessaire de connaître les *formes structurales* avant d'entreprendre l'analyse des *fonctions* de n'importe quel vivant. La biologie a passé de l'observation de la structure macroscopique à l'examen microscopique, puis submicroscopique, de son infrastructure. Pendant longtemps – et c'est encore parfois le cas aujourd'hui – le *morphologiste* et le *physiologiste* travaillaient indépendamment l'un de l'autre. Avec l'emploi du microscope électronique et la mise au point de techniques particulières, le biologiste pourra désormais décrire des organites intracellulaires en même temps qu'il en déterminera le fonctionnement. Peu à peu, un nouveau type d'expérience [6] prend naissance, qui permettra l'étude simultanée de la structure et des mécanismes réactionnels.

Parallèlement, l'explication des fonctions biologiques, tout imprégnée de biochimie et de biophysique, fera appel, de plus en plus, à des processus qui se déroulent au niveau des molécules opérationnelles. Une nouvelle biologie est née: la *biologie moléculaire*.

Cependant, en voulant ramener les fonctions vitales à une série de processus qui ne se situent même plus au niveau des tissus ou des cellules, même pas dans les organites dont ces cellules sont faites, mais à l'échelle de quelques groupes d'atomes réactifs, le biologiste doit être conscient que les interprétations qu'il suggère ne concernent plus tout à fait le vivant lui-même.

Dans un proche avenir, il conviendra de vérifier sur l'organisme «entier» les observations accumulées aux dépens de ses «parties». Mais on ne saurait trop relever les avantages des méthodes actuelles qui, si elles ne permettent pas l'examen des fonctions *in vivo*, offrent la possibilité de les analyser *in vitro* dans les conditions d'étude les plus favorables.

On a parfois tendance à oublier que la science de la vie peut correspondre à divers *niveaux d'intégration*. Il est clair que, avec les méthodes actuelles, les résultats les plus spectaculaires ont été obtenus au *niveau moléculaire* et au *niveau cellulaire* de la matière vivante. Mais les niveaux plus macroscopiques, et par conséquent plus anciennement étudiés, correspondant aux *tissus*, aux *organes*, à l'*individu* où la *population* d'organismes et la *biosphère* existent et exigent aussi de la part du biologiste quelque attention. A ce propos, rappelons les divers «étages», de plus en plus complexes, qui caractérisent le monde vivant et qu'un enseignement moderne de biologie se doit d'examiner, tant du point de vue descriptif que du point de vue fonctionnel. Ces niveaux – dont la nature et l'amplitude changent suivant les auteurs – forment un véritable «spectre biologique», dont celui d'Odum est le type. Ils commencent par un

palier relativement simple et s'achèvent par un étage compliqué puisqu'il procède de tous les autres. Nous suggérons, à titre d'exemple, le spectre suivant :

- | | | |
|-------------------|---------------------------|---------------------|
| 1) les molécules | 5) les tissus | 9) les populations |
| 2) les organites | 6) les organes | 10) les communautés |
| 3) le protoplasme | 7) les systèmes d'organes | 11) les écosystèmes |
| 4) les cellules | 8) les individus | 12) la biosphère. |

Lorsque le mot de *biologie* fut créé par LAMARCK et TREVIRANUS [7], il était apparu d'emblée qu'une science des vivants (ou de la vie) devait être possible. Cependant, pour beaucoup, la biologie reste encore la science de l'être animé ; les idées anciennes ont souvent longue vie . . . L'animal est vivant, la plante ne l'est point . . . dit-on parfois ! Aussi, certains enseignants ne laissent qu'une place très maigre – s'ils en laissent – à la biologie végétale. Comme l'écrivait A. GUILLERMOND [8], les végétaux « . . . ne diffèrent essentiellement des animaux ni par leur organisation, ni par leur métabolisme et ont l'avantage d'être beaucoup plus accessibles à l'expérimentation ; ils permettent d'aborder avec plus de facilité la plupart des problèmes fondamentaux de la biologie et de les éclairer ». De plus, la biologie végétale se prête mieux à l'étude des structures et des fonctions cellulaires ; comme le remarquait L. PLANTEFOL [9] « . . . la vie des plantes est, en un sens, plutôt l'œuvre de leurs cellules, tandis que celle des animaux est plutôt l'œuvre de leurs organes ».

La biologie est donc bien la science de la vie, d'une *vie animale aussi bien que d'une vie végétale*. Dans les dernières classes des lycées, il serait discutable de ne point chercher à équilibrer les notions fondamentales relatives à la fois aux formes animales et aux structures végétales. On n'insistera jamais assez sur l'importance et les conséquences d'un tel enseignement – dont nous reparlerons plus loin. H. J. MULLER [10] n'hésite pas à écrire de la biologie « . . . c'est aussi de beaucoup la branche la plus utile des connaissances humaines, la seule qui puisse sauver l'individu et la société du désastre et assurer la marche régulière et prolongée du progrès ». La plupart des futurs étudiants n'auront de la biologie que l'image qui leur aura été présentée avant leur baccalauréat. Et pour ceux qui pratiqueront plus tard les sciences biologiques, ils devront en savoir assez pour choisir ensuite leur orientation. Cette biologie se doit d'être, par conséquent, non seulement actuelle, mais cohérente et harmonieusement équilibrée.

3. La biologie et les autres disciplines scientifiques

Quelle que soit l'orientation choisie par le biologiste – et même si celui-ci est décidé à faire de la biologie strictement descriptive – les besoins en « sciences-

supports» sont évidents. Tout biologiste demande en effet aux sciences mathématiques, physiques et chimiques, des services de trois ordres, c'est-à-dire des *données de base*, des *techniques* et une *éducation de l'esprit* [11].

L'outil mathématique a pris, dans les sciences biologiques d'aujourd'hui, une place de premier ordre, et son usage de plus en plus fréquent s'impose toujours davantage [12]. Comment ne pas utiliser les mathématiques lorsque, sans cesse, le biologiste doit mesurer des grandeurs et exprimer le déroulement de phénomènes. Si la description des structures implique des références à des critères géométriques, l'analyse des fonctions entraîne automatiquement la définition préliminaire de paramètres précis. De plus, en biologie taxonomique ou systématique, comme d'ailleurs en biologie expérimentale, le calcul statistique est constamment sollicité.

L'utilisation de la physique et de la chimie en biologie est suffisamment évidente pour qu'il ne soit pas nécessaire d'allonger notre propos. Il est impossible d'entreprendre une quelconque expérience sur un matériel vivant sans des connaissances de physique, et notamment d'électricité et d'optique. Il est, d'autre part, bien difficile aujourd'hui, d'expliquer un mécanisme biologique sans faire intervenir des notions, pas toujours élémentaires, de thermodynamique et de physique quantique. Pour la chimie, la situation est à peu près semblable. Des éléments de chimie analytique, de chimie minérale et de chimie organique sont absolument indispensables aussi bien en laboratoire, où chaque technique en use sans cesse, que dans l'observation des processus étudiés. En outre, il n'est pas possible d'ignorer l'opinion très répandue – encore qu'elle l'est de moins en moins – que la biologie est une discipline plus facile et moins importante que les mathématiques, la physique et la chimie [13]. En obligeant les futurs biologistes à s'astreindre à ces enseignements, cette «hiérarchisation» discutable s'atténuera et des jeunes gens suivront leur vraie vocation sans idée préconçue.

Il résulte de ce qui précède qu'un enseignement de biologie – même un peu élémentaire – ne peut se faire valablement sans que les étudiants aient eu déjà des enseignements de mathématique, de physique et de chimie. Cette remarque est essentielle; nous reviendrons sur ces problèmes plus loin.

4. *La biologie et l'enseignement universitaire*

Il ne sera question ici que des enseignements généraux de biologie, c'est-à-dire de ceux qui sont donnés au cycle propédeutique. Nous n'examinerons pas les problèmes que posent les enseignements spécialisés (II^e et III^e cycles) qui ne concernent plus exactement la biologie générale mais portent essentiellement sur la physiologie, l'écologie, la microbiologie, la chimie biologique, la génétique et les disciplines relatives à la taxonomie végétale et animale.

Il y a encore peu de temps, la biologie était enseignée parallèlement à la physique et à la chimie au cours de la première année propédeutique. Ce système est encore pratiqué dans certains pays, mais pas pour longtemps semble-t-il [14]. Il est heureusement apparu à certaines autorités académiques qu'il n'était plus possible d'enseigner valablement la biologie sans que l'étudiant n'ait eu, au préalable, des cours de mathématiques, de physique et de chimie. Nous avons déjà parlé plus haut de la situation particulière de la biologie à l'égard des autres disciplines; cette interdépendance justifie parfaitement la mise au point de programmes étalés sur deux ans, avec la biologie prévue en seconde année.

A titre d'exemple, nous donnerons le plan d'étude adopté à la Faculté des sciences de Lausanne pour les étudiants candidats à la licence et au diplôme de biologiste (1^{er} cycle d'étude).

<i>Première année</i>	Semestre I (Hiver)			Semestre II (Eté)		
	<i>C</i>	<i>R/E</i>	<i>TP</i>	<i>C</i>	<i>R/E</i>	<i>TP</i>
Mathématiques générales	4	2	—	4	2	—
Physique expérimentale	5	1	4	5	1	4
Chimie générale	5	1	4	—	—	8
Chimie organique	—	—	—	6	—	—
<i>Seconde année</i>	Semestre III (Hiver)			Semestre IV (Eté)		
	<i>C</i>	<i>R/E</i>	<i>TP</i>	<i>C</i>	<i>R/E</i>	<i>TP</i>
Biologie cellulaire et végétale	4	—	2	4	—	4
Biologie animale et anatomie comparée	5	—	4	5	—	4
Botanique comparée	1	—	—	1	—	4
Zoologie comparée	1	—	4	1	—	—
Géologie	3	—	4	2	—	4
Statistique	2	1	—	2	1	—
<i>C</i> : cours <i>R</i> : répétition <i>E</i> : exercices <i>TP</i> : travaux pratiques						

La formule adoptée ici présente des avantages évidents. Elle permet tout d'abord des enseignements de biologie dans d'excellentes conditions, puisqu'ils sont donnés après qu'aient été présentées les disciplines de base, c'est-à-dire les mathématiques générales, la physique expérimentale et la chimie. D'autre part, cette solution a permis d'alléger le programme tout en augmentant les types d'enseignements. Il suffit d'imaginer ce qu'étaient les horaires de nos étudiants en sciences qui, en une seule année, devaient suivre des cours, des exercices et des travaux pratiques de mathématiques, de physique, de chimie, de sciences biologiques et de géologie.

En *diversifiant* et en *regroupant* les enseignements, il a été possible de les *spécialiser*. Etalés sur deux ans, les programmes propédeutiques ont pu être ainsi notablement augmentés, alors que pour chacune des deux années le nombre d'heures hebdomadaires s'en trouvait réduit d'une façon appréciable. Cette formule a permis de satisfaire à des exigences tout à fait légitimes. Les connaissances aujourd'hui absolument indispensables au futur biologiste ont considérablement augmenté. Il lui faut savoir beaucoup plus des éléments des sciences fondamentales et il ne peut ignorer les notions de base d'une biologie classique et élémentaire.

On remarquera que, dans ce programme, une part est faite à la biologie descriptive. Il faut que l'étudiant, le plus souvent attiré par la biologie expérimentale, prenne contact d'abord avec les sciences naturelles fondamentales. Après deux années propédeutiques, il pourra en connaissance de cause choisir l'orientation qui lui convient le mieux, ayant eu, pendant la seconde année, l'occasion de prendre contact avec les disciplines essentielles de la biologie traditionnelle.

Ainsi, les enseignements de biologie au premier cycle de l'Université sont-ils ou deviennent-ils plus cohérents et par là, mieux adaptés aux exigences actuelles. Nous ne saurions passer sous silence l'intéressant article de notre collègue le professeur F. E. LEHMANN [15] qui traite de la situation, un peu différente, des universités de Suisse allemande. Retenons de cette étude les grandes lignes d'un programme de biologie générale qui pourrait servir de modèle à des cours regroupés de biologie animale et végétale.

Etude du monde dans le milieu humain (écologie, paléontologie, évolution)

Phénomène de base de la vie (histologie, organisation . . .)

Morphologie fonctionnelle – génétique – embryologie

Anthropologie biologique

Un problème cependant doit être discuté; il concerne aussi – bien que dans une moindre mesure – nos lycées, gymnases et collèges. Sans doute est-il essentiel de discuter un programme, d'en prévoir les principes généraux et d'établir les grandes lignes de son application, mais une question importante demeure. Elle touche directement ceux qui seront chargés de mettre en pratique ce programme et d'assurer en quelque sorte sa réussite. En d'autres termes, la qualité des *enseignants* joue un rôle aussi grand – sinon plus grand – que le choix des matières enseignées. Cette question sera discutée à la fin de cet article.

5. La biologie et l'enseignement secondaire

1. Les types d'enseignements

Les buts que l'enseignement des sciences biologiques vise, au niveau de nos écoles secondaires, sont nombreux et variés [16]. Il convient de former

l'intelligence de jeunes gens qui, plus tard, mais pas nécessairement, seront assis sur les bancs de nos auditoriums universitaires. Les maîtres responsables chercheront à apprendre à leurs élèves à penser clairement, à s'exprimer fidèlement et à prendre confiance dans leur propre raisonnement. Sans nier, bien au contraire, la valeur formatrice des mathématiques, sans vouloir réduire le moins du monde l'étude des langues et de la langue maternelle en particulier, en conservant aux humanités la place de choix qu'elles méritent, il nous paraît que la biologie doit avoir elle aussi une part appréciable dans les programmes.

Examinons successivement, et pour les divers niveaux des classes de nos collèges et gymnases ou lycées, ce que pourraient être les enseignements de biologie élémentaire.

Dans les classes inférieures de l'enseignement secondaire, celles du premier et du second degré, il existe une «branche» qui exerçait (et qui, nous le croyons, exerce encore) sur les écoliers un attrait incontestable: nous voulons parler des *leçons de choses*, le plus bel ornement des programmes des lycées, comme le disait un inspecteur de l'enseignement en France, il y a quelques mois.

L'histoire naturelle, pour les élèves de dix à treize ans, c'est un monde attirant, plein de mystères et de promesses, celui de la vie avec ses énigmes passionnantes. Douze ans, c'est l'âge où l'enfant aime à collectionner plantes, insectes ou cailloux, où, dans sa chambre, il conserve dans des bocaux tout un monde aquatique dont il suit la vie surprenante. Le maître se doit d'utiliser cet enthousiasme et de profiter de ce terrain particulièrement favorable. Ce qui captive l'écolier, c'est la chose en soi, son mouvement, expression de sa vie et peut-être de son âme. Ce qui compte, c'est l'être vivant ou la matière, avec son existence propre et définie dans un cadre que l'adulte ne sait plus ou ne veut plus comprendre. Cet état d'esprit, nous dirons que c'est peut-être la caractéristique la plus remarquable de l'enseignement à ce niveau. L'élève, sous la direction d'un maître enthousiaste et compétent, sera placé en face de ces «choses» qui l'attirent. C'est dans cette leçon, trop rare à notre gré, qu'il apprendra vraiment à former son jugement et à préciser, sans effort, comme par jeu, une méthode de travail qu'il n'oubliera pas. Avec la description d'une fleur, ou d'un animal, il apprendra à utiliser le mot propre, il s'initiera à la discussion, à la confrontation de l'exposé, il sera obligé de s'exprimer clairement et simplement. Le maître n'aura certes pas la tâche facile. Car l'enfant est curieux, et devant un fait, il pense automatiquement à d'autres faits qu'il rapporte et pour lesquels il demande une explication. Le sens de l'observation, de la critique, de la discussion, de la synthèse, de l'exposé plus général, il va l'acquérir. Peu à peu, quelle richesse ne peut-on pas amasser dans une leçon de choses, le plus bel enseignement peut-être qu'un scientifique puisse donner! L'élève, tour à tour spectateur et artisan, apprendra à se servir de ses doigts pour disséquer un animal ou monter une petite expérience, il s'astreindra à

un travail soutenu, il apprendra à se concentrer, il réalisera en petit tout ce que, plus tard, dans un laboratoire de recherche, il sera peut-être appelé à faire en grand. Sans porter un jugement de valeur sur les enseignements scientifiques qui viendront plus tard, c'est dans le cadre de cet enseignement modeste des leçons de choses, pensons-nous, que naissent les vocations, que se décide une carrière. A ce niveau-là, le maître est appelé à jouer un rôle de premier plan. Mais il n'est pas question ici uniquement du «pédagogue» dont la tâche essentielle est de communiquer un savoir bien structuré et de contrôler, à l'occasion, si les notions exposées ont été convenablement apprises par les élèves. Le maître doit être avant tout un guide, proche de son auditoire, préoccupé davantage de lui faire découvrir les faits biologiques que de lui imposer une science toute faite, livresque et souvent indigeste. Ce maître n'aura pas la tâche facile, il lui faudra suivre ses élèves, les corriger, leur apprendre à s'exprimer correctement, à rendre compte avec précision des observations qu'ils auront soigneusement enregistrées. A cet égard, le maître de biologie peut jouer un rôle capital dans la formation des jeunes gens. L'enseignement des sciences de la vie, prendra alors sa vraie signification: il permettra la formation et la mise à l'épreuve d'une rigoureuse technique de travail et en même temps d'une méthode générale de pensée.

Quelques mots maintenant de l'enseignement dans les dernières années de l'école secondaire.

Alors que dans les classes inférieures de nos collèges le ton «leçon de choses» doit être conservé, le maître passant d'un sujet à l'autre sans choix prémédité, au gré des saisons et des intérêts, dans les classes supérieures, les problèmes et le propos changent. La leçon de choses s'efface devant la *leçon de sciences*. L'objet qui avait sa valeur particulière, son monde à lui, va s'intégrer dans un tout. La notion de sciences spéciales s'impose. A l'étude de la chose en soi succède l'analyse d'un problème général. A l'examen de la forme d'un être, succède l'étude de la fonction des êtres. Dans les dernières années du collège, un tel enseignement peut être très efficace. Sur divers types d'êtres vivants, aussi dissemblables que des cellules de levure, des plantes évoluées et des animaux domestiques, par exemple, l'étude expérimentale de la fonction paraît séduisante. Le maître, en choisissant le matériel le plus commode, abordera sans peine l'examen de quelques grandes fonctions qui caractérisent le vivant. Avec des moyens simples, il introduira ses élèves dans le monde de l'expérience. Il leur apprendra la méthode de recherche, harmonieusement ordonnée, de ceux qui travaillent à une autre échelle à résoudre les problèmes de la vie. Ainsi la formation de l'enfant se complètera chez l'adolescent, en même temps que sa culture générale se précisera. Et à ce propos, on ne le rappellera jamais assez, la culture n'est pas faite essentiellement, pour ne pas dire exclusivement, de connaissances littéraires, historiques ou artistiques, elle est aussi la connais-

sance de soi, de son corps et de ses fonctions et celle des vivants en général. Les sciences au collège, auxquelles on accorde, en ces temps où la civilisation est tout imprégnée de données et de réalisations scientifiques, une place malheureusement minimale, visent ainsi non seulement à donner aux jeunes une méthode, mais encore à préparer pour eux une culture.

Sans doute, parmi les innombrables problèmes qu'on souhaiterait voir traiter dans les classes terminales du collège et les premières classes du gymnase, il faut choisir, et ce choix n'est pas toujours facile. Empruntons à RENSCH [17] un programme qui n'est pas sans intérêt.

Différences entre animaux et végétaux

Immortalité potentielle de la matière vivante

Fonctions des principaux organes de l'homme

Hormones

Comportement

Génétique – Evolution et ascendance humaine – Problèmes de surpopulation et de descendance génétique – Ecologie.

Quel sera alors l'enseignement à donner au gymnase ou dans les dernières classes de nos lycées ? Ici, les difficultés peuvent paraître insurmontables. Les notions de base manquent encore au gymnasien, il est par conséquent impossible de faire une «biologie explicative». Mais l'élève ne saurait accepter – et il aurait raison – un enseignement strictement descriptif. On exige de lui, dans la plupart des disciplines enseignées, de grandes qualités de raisonnement et de mémoire, pourquoi faut-il que le niveau des leçons de biologie soit inférieur ? Que proposer alors comme programme d'enseignement ?

Après la *leçon de choses* et les *leçons de sciences*, un seul type de leçon nous paraît logiquement réalisable et réellement praticable, nous la baptiserons «*leçon de la pensée scientifique*». A propos de quelques grands sujets, entrevus au collège, du moins par l'ensemble des faits qu'ils ont permis d'accumuler, l'histoire de leur découverte apparaît logiquement. Il n'est plus possible aujourd'hui, dans le cadre de l'enseignement secondaire, de proposer à l'élève une explication de la plupart des processus vitaux. La biologie est en fait un carrefour, où se croisent sans cesse des sciences comme la physique, la chimie-physique et la chimie. Vouloir expliquer un phénomène, même très simple, c'est être obligé de faire appel à des notions qui, au gymnase, ne sont pas encore assimilées ou sont même inconnues. Le maître évitera les explications fausses, les «coups de pouce» désastreux dont se contentent hélas trop souvent ceux qui veulent expliquer à tout prix. Mais l'élève, lui, se pose des questions. L'histoire des sciences lui donnera satisfaction. En étudiant l'évolution d'un problème, le gymnasien fera connaissance avec les étapes qui la caractérise. Peu à peu, il sera amené à juger des explications, à prendre parti pour ou contre

des théories qu'il pourra le plus souvent assimiler, parce qu'elles ont été établies autrefois, au moment où la connaissance du savant était à peu près celle, en ce qui concerne les problèmes fondamentaux, du gymnasien actuel. A. REYMOND écrivait à ce sujet « . . . L'histoire des sciences passe au crible les méthodes et les théories récemment acquises des diverses sciences à une époque donnée; les résultats obtenus par cet effort critique sont particulièrement précieux pour élucider le passé, lui restituer l'incertitude de l'avenir, montrer les voies possibles qui s'ouvraient, les hésitations puis les avantages et les inconvénients du choix opéré » [18]. Cet enseignement, qu'on pourrait concevoir comme une suite de chapitres choisis, mettra en garde les jeunes gens contre les idées préconçues, les théories insuffisamment liées à des faits expérimentaux précis. Là encore, la méthode de travail des chercheurs sera un exemple pour l'élève. L'histoire des sciences, ou plus exactement l'histoire de quelques problèmes scientifiques lui permettra d'enrichir son bagage, elle l'amènera à la connaissance, sur un plan supérieur, de l'homme.

Il ne faudrait pas cependant qu'on nous accuse de réduire cet enseignement à des notions anciennes et périmées et de condamner les enseignants à faire de l'histoire – de la petite histoire – des sciences. Il s'agit, en fait, d'une véritable « méthodologie scientifique » qui devrait permettre, à l'occasion de discussions sur les travaux classiques et surtout sur les méthodes de quelques biologistes, des allusions constantes aux données modernes. Cette continuelle référence à la science d'aujourd'hui replacerait les recherches dans un contexte actuel. En somme, cet enseignement vise essentiellement à actualiser le passé. Dans cette perspective, il répondrait très exactement au point de vue de F. GONSETH [19]; n'est-il pas en effet une permanente ouverture – suggérée aux jeunes – vers la biologie de notre temps? Et cette ouverture serait essentiellement axée sur l'étude des méthodes traditionnelles.

Il est évident que l'ordre strictement historique habituel à la présentation des connaissances doit être absolument abandonné. Cette conception de l'enseignement de la pensée scientifique n'exclut pas – comme le faisaient judicieusement remarquer PH. L'HERITER et G. RIZET [20] – l'intérêt pour ce genre d'enseignement.

Ce programme – s'il offre quelques légers inconvénients, dont la difficulté de trouver des maîtres capables d'assurer un tel enseignement – et nous en reparlerons plus loin – présente d'innombrables et incontestables avantages.

Un tel enseignement fera connaître les premiers travaux sur lesquels reposent les bases de la biologie d'aujourd'hui. Il vise donc à une culture générale où la connaissance des « classiques » est intimement associée aux recherches présentes. En acceptant cette conception pédagogique, on évitera de faire une biologie trop descriptive qui rebute souvent les jeunes et on pourra – malgré

les faibles bases de physique et de chimie – présenter tout de même une «biologie en marche».

2. Du niveau des leçons de biologie

Un fait est frappant et – du moins dans les pays d'expression française – il paraît général. Quel que soit le degré d'enseignement, de la simple leçon de chose au cours de biologie avant le baccalauréat, on peut constater combien, en fin de compte, sont peu nombreuses les exigences que l'on a vis-à-vis des élèves dans les classes de sciences naturelles. En tous les cas – et je ne serai pas le premier à faire cette remarque – il faut bien convenir que l'on demande, en biologie, beaucoup moins à l'élève que dans d'autres branches – comme les mathématiques et les langues. Il n'est point dans l'objet de cet article de discuter des disciplines imposées autres que les sciences naturelles. Il serait pourtant intéressant de se livrer à une étude comparée et d'examiner, pour chaque degré, la part de la mémoire, du raisonnement, de la méthode de travail, en un mot de l'intelligence, exigée pour toutes les branches inscrites au programme. M'étant livré – pour une année précise de la scolarité de nos gymnasiens, à cet exercice, il m'est apparu que la biologie était vraiment, à cet égard, le parent pauvre. Alors que l'élève est astreint à une rigoureuse discipline en mathématiques où les maîtres insistent sur le raisonnement, la clarté de la pensée, alors que ces mêmes élèves, dans les leçons de langue, sont entraînés à rédiger des dissertations, des thèmes et des versions, que leur apportent les leçons de biologie? Des faits pas toujours compris et souvent, à ce degré, inexpliqués, peu de matière où le raisonnement l'emporte sur la mémoire, des connaissances, surtout livresques et pas toujours adaptées à leur propre intérêt et à l'état présent de la science. La biologie est vraiment une discipline de second plan, voire même une branche sacrifiée. Les élèves ne pourront pas s'empêcher d'établir alors une hiérarchisation de valeur où les sciences de la vie n'auront guère une place de faveur, loin de là. Cette situation de «branche très secondaire» est évidemment fort discutable. Elle n'est pas favorable à la biologie que la plupart des futurs bacheliers considèrent comme une science de second ordre et qui, il faut bien l'avouer, risque de tenter avant tout les élèves peu doués pour les mathématiques ou pour les disciplines littéraires. Et pourtant les sciences biologiques, outre les débouchés de plus en plus nombreux qui s'ouvrent vers la recherche fondamentale ou appliquée, sont la nécessaire introduction à l'étude des sciences médicales par exemple.

Comment remédier à cet état de chose? Par quels moyens élever le niveau des enseignements de biologie, stimuler l'intérêt des élèves pour les sciences de la vie et leur permettre de choisir objectivement leur spécialité future sans qu'il y ait des branches sacrifiées? Un exemple précis suffira à préciser cette situation. Dans les programmes – fixés par l'arrêté du 10 octobre 1958 – des

classes terminales des lycées français, programmes par ailleurs fort bien faits, on trouve, en guise d'introduction, les sujets suivants :

plans d'organisation d'un animal vertébré (autant que possible un Mammifère) et d'une plante à fleur (Angiosperme) dégagés par l'observation et la dissection.

Loin de moi l'idée de critiquer le programme dont le premier chapitre est incriminé. Je trouve ce programme au contraire excellent et souhaiterais qu'il soit davantage suivi ailleurs. En effet, les grands thèmes d'une biologie plus expérimentale que descriptive y sont représentés et ceci aussi bien par l'étude – harmonieusement équilibrée – des végétaux et des animaux. Mais est-il opportun de faire débiter un tel enseignement de biologie, destiné à des élèves qui en sont à leur dernière année d'enseignement secondaire, par une étude macroscopique qui les ramène – quel que soit le ton de la leçon – aux enseignements élémentaires de sciences naturelles ? Hélas, la Souris et le Haricot seront, dans trop de classes, suivis d'autres plantes et d'autres animaux. Et la comparaison avec ce qui est enseigné en mathématiques et ailleurs n'est guère favorable à la biologie. Cette science restera pour des volées de bacheliers le type même de la science « contemplative », facile mais ennuyeuse et par conséquent juste digne des moins doués d'entre eux.

Et pourtant, les sciences de la vie offrent d'inépuisables ressources pour ces cours de fin de scolarité. Sans vouloir rechercher à tout prix des questions qui impliquent une accessible explication – et nous avons vu plus haut combien cela pouvait être difficile – il est d'innombrables sujets où l'on peut discuter et élever le niveau de la leçon. En abordant des problèmes touchant à l'hérédité, à la reproduction, au métabolisme, à l'évolution . . . , le maître se trouvera face à un auditoire attentif, intéressé et constamment sollicité par des exercices de réflexion dont la rentabilité est évidente.

Ainsi structuré, l'enseignement de la biologie dans les classes supérieures de nos lycées permettra un utile bagage à ceux qui ne feront plus de biologie et donnera la possibilité aux futurs biologistes de choisir intelligemment et sans parti pris l'orientation la plus conforme à leurs intérêts scientifiques. Et puis, on peut espérer qu'un tel enseignement favorisera les vocations et engagera des jeunes, indécis quant à leur future carrière, à se diriger vers les sciences biologiques.

3. Les travaux pratiques

Il n'a été question jusqu'ici que du seul enseignement *ex cathedra* : il convient de dire quelques mots des travaux pratiques. Nul ne conteste aujourd'hui leur importance et chacun admet que l'élève tirera grand profit de contacts répétés avec l'expérimentation.

Les *leçons de choses* et de *sciences* doivent être à tout prix illustrées par des exercices auxquels les élèves prennent part. Cependant, à ce degré, les mani-

pulations visent davantage à l'information qu'à «l'apprentissage» de la méthode expérimentale proprement dite. Le fait à observer est plus important que la technique elle-même qui permet cette observation. Convenons toutefois que de tels exercices – s'ils n'apportent pas à l'élève la vraie technique biologique – lui fournissent l'occasion de se familiariser avec l'expérience et lui donnent, en fait, les premières bases d'une méthode de travail.

La situation est toute différente dans les classes supérieures. Les travaux pratiques devront, ici, compléter l'enseignement théorique. C'est à ce niveau-là que les jeunes gens feront réellement connaissance avec la méthode expérimentale. Lorsque, dans le cours de biologie – et pour suivre le programme suggéré dans cet article – il sera fait allusion aux expériences réalisées par les chercheurs, l'élève aura l'occasion, aux travaux pratiques, de refaire ces essais, de les discuter, voire de les critiquer à la lumière des travaux plus récents. Les exercices de biologie seront alors une véritable initiation à la technique expérimentale. N'est-ce pas là la meilleure des introductions à un enseignement plus avancé de biologie moderne ?

Sans doute le choix des manipulations n'est-il guère facile. Mais il nous semble que les exercices doivent surtout viser à la simplicité expérimentale et porter sur des matières élémentaires. Il faut se garder de ces sujets «prétentieux» qui donneront aux élèves l'illusion d'un savoir étendu. Ces travaux pratiques devraient leur apporter avant tout une méthode rigoureuse et non point un bagage supplémentaire de faits nouveaux. Peu importe si les résultats à obtenir sont déjà familiers; ce qui compte, c'est la mise au point d'une méthode, la discussion des valeurs expérimentales obtenues. Un premier exemple montrera ce que l'on peut considérer comme valable; dans un second, nous verrons ce qui peut correspondre à un échec.

Imaginons que le sujet «*la fermentation alcoolique*» soit proposé à une équipe de jeunes gens. Les faits essentiels sont connus et les élèves ont vu, au cours, comment, peu à peu, par une rigoureuse expérimentation, on est arrivé à une solution acceptable de ce problème. Le groupe commencera par se partager le travail; les élèves s'initieront ainsi à cette recherche en équipe si essentielle aujourd'hui en biologie. Les uns se pencheront sur les propriétés des levures, leurs caractéristiques morphologiques et physiologiques. Les autres mettront au point quelques expériences élémentaires visant à l'analyse des réactions. Tous essaieront de mesurer, par exemple, les effets de la température. Les résultats, soigneusement protocolés, seront discutés et critiqués. On comprend aisément que, dans ces essais, ce n'est pas le fait en soi qui importe, mais seule la méthode.

Le second exemple vise à démontrer l'inutilité de certains exercices. Supposons que l'on propose aux élèves d'étudier . . . les *vitamines*. Voilà un beau titre, en vérité! Mais ne couvre-t-il pas – sous prétexte de «modernisme» – un

sujet à la fois trop vaste et trop compliqué? Les élèves devront se limiter à quelques essais accessibles. Pendant des semaines, ils auront à se livrer à de fastidieuses opérations: préparation de solutions – dans des conditions difficiles – pesées et arrosages, corvées d'alimentation... La vertu éducative de tels exercices est plutôt maigre. Les élèves n'auront pas appris ce qu'est la méthode biologique, tout au plus auront-ils fait connaissance avec certaines techniques réalisées, dans un laboratoire de recherches biologiques, par la laborantine ou un technicien.

Dans ces travaux pratiques, les élèves s'initieront vraiment à la méthode expérimentale. En répétant certaines expériences classiques – facilement réalisables parce que mises au point à une époque où l'instrumentation n'était pas ce qu'elle est aujourd'hui – ils apprendront vraiment les conditions de travail du biologiste. Dans cette perspective, les cours et les exercices pratiques se complèteront harmonieusement. A ceux qui ne feront plus de biologie, un tel enseignement aura donné une idée vraie de ce que la biologie peut être. Pour ceux qui, au contraire, à l'Université, se dirigeront vers les sciences biologiques et médicales, cet enseignement sera une excellente introduction à leurs études à venir.

6. *Les enseignants*

Il est bien clair que le meilleur des programmes et le plus excellent des plans d'étude ne vaudront jamais que par les qualités pédagogiques et scientifiques de ceux qui ont la charge de les mettre en pratique, qu'ils soient professeurs d'université ou maîtres dans les classes supérieures de nos collèges. Si l'on veut que l'enseignement soit bien donné, il faut mettre tout en œuvre pour élever le niveau des enseignants. Or la biologie, tout particulièrement, est aujourd'hui dans une fâcheuse position. A l'enseignement, les jeunes préfèrent la recherche et comme l'on tend à mieux considérer la recherche que l'enseignement, on se trouve peu à peu devant une pénurie de maîtres de lycées. D'autre part, on rencontre encore bon nombre de gens qui estiment nécessaire de distinguer entre chercheur et «pédagogue», l'un ne pouvant être l'autre en même temps!

Ainsi, *l'enseignement universitaire*, lui aussi, est menacé. Cette façon de voir nous paraît peu soutenable. A notre avis, un professeur d'université doit être doublé d'un chercheur. S'il fait de la recherche, ses cours seront certainement meilleurs (il saura communiquer son enthousiasme et se tiendra plus facilement au courant des dernières acquisitions de la science) et il pourra plus efficacement diriger ses collaborateurs. S'il donne un enseignement, il conservera – ce qui est indispensable – un contact avec les étudiants et sera obligé de formuler clairement ce qu'il veut expliquer (gymnastique intellectuelle évidemment nécessaire à celui qui fait de la recherche). En allégeant les obliga-

tions d'un professeur d'université et en chargeant les chercheurs d'un enseignement, le problème, du point de vue de l'enseignement académique, sera résolu.

A l'échelon de *l'enseignement secondaire*, bien qu'à une moindre échelle, de semblables problèmes se posent. Si le maître de lycée ou de collège avait la moitié, ou mieux le tiers des charges d'enseignement qu'il a généralement aujourd'hui, il pourrait sans peine entreprendre un travail de recherche. Son enseignement n'en serait que meilleur et il se tiendrait ainsi constamment en contact avec la science. L'opposition détestable entre chercheur et enseignant serait ainsi évitée, la qualité des uns et des autres pourrait – on l'imagine sans peine – être nettement améliorée et l'on aurait à offrir à de futurs biologistes des postes qui permettraient de satisfaire à la fois leurs goûts pour l'enseignement et pour la recherche. Du même coup, on éviterait dans les collèges certains de ces maîtres «peu doués» qui sont incapables de faire valablement de la recherche, qui sont aussi des médiocres enseignants, mais qu'il est nécessaire d'utiliser faute de professeurs qualifiés.

Avec un maître que l'enseignement ne surcharge pas trop et qui, de ce fait, prend part directement à la recherche, la biologie à tous les degrés sera alors entre de bonnes mains et il n'aura pas été inutile alors d'essayer de restructurer les programmes d'enseignement.

Quelques remarques encore nous paraissent indispensables. Il convient d'insister tout d'abord sur le caractère très particulier de l'enseignement des sciences biologiques et, par conséquent, sur la formation rigoureuse de ceux qui en ont la charge. Un tel enseignement n'est pas toujours «gradué» comme c'est le cas en mathématiques par exemple. On conçoit mal qu'un élève pose à son maître des questions qui dépassent très largement le programme d'algèbre traité. Par contre, à quelque degré que ce soit, on imagine très bien des jeunes gens interrogeant leur professeur de biologie sur des questions qui échappent totalement aux sujets discutés dans les leçons. Est-il besoin de rappeler ce que peut être une leçon de choses où des écoliers apportent au maître des plantes à déterminer, des nids d'oiseaux à reconnaître et qui, à propos de la dissection de la fleur du Cerisier, sont entraînés à poser des questions portant aussi bien sur la fécondation, l'hérédité que l'évolution? Et que dire des cours de biologie des classes supérieures où la curiosité des élèves est du même ordre et les pousse à interroger leurs maîtres sur des problèmes complexes. La culture du maître de biologie doit donc être très large et on comprend que l'enseignement des sciences de la vie ne peut être donné que par un spécialiste. On n'insistera donc jamais assez sur l'importance de la formation universitaire d'un futur enseignant. A n'importe quel degré, les sciences biologiques devraient être enseignées par un biologiste. Il est hélas courant que l'enseignement des leçons de choses soit attribué, faute de personnel enseignant, à des maîtres de français par exemple. Sans vouloir discuter les talents pédago-

giques et même la bonne volonté de tels maîtres, il faut bien reconnaître que leur enseignement ne pourra plus correspondre aux buts qui leur avaient été assignés. Les leçons de choses qui devraient être une réelle découverte de la vie et en même temps une initiation à la méthode scientifique, deviennent, dans de telles conditions, de fastidieuses leçons de vocabulaire où l'élève ne retiendra de la biologie ainsi enseignée qu'une liste de mots sans aucune signification concrète.

On l'a dit plus haut, le maître responsable de l'enseignement des sciences biologiques doit posséder un certain nombre de qualités qui ne sont pas nécessairement . . . incompatibles. Ayant reçu une bonne formation universitaire, il ne peut ignorer que les connaissances biologiques se modifient très vite. Il devra par conséquent se tenir constamment au courant des dernières acquisitions de cette science. Mais il lui faudra aussi être un pédagogue et, à côté de dons naturels qu'il cherchera évidemment à développer, il ne pourra pas se tenir à l'écart des récentes techniques d'enseignement.

Que fait l'Université, aujourd'hui, pour aider le futur maître de biologie à accomplir sa tâche? Lui donne-t-elle la possibilité, dans ses laboratoires, d'apprendre son métier d'enseignant? Lui offre-t-elle, après, les moyens de se perfectionner ou tout simplement de reprendre contact avec la science? Il faut bien le reconnaître, l'Université se préoccupe fort peu du sort de celui qui enseignera la biologie lorsqu'il l'aura quittée.

Sans doute, nous dira-t-on, des centres pédagogiques ont été créés un peu partout et l'étudiant, sa licence terminée, aura à y suivre des cours de didactique, de pédagogie et devra donner des leçons dirigées. Mais est-ce suffisant? Pour notre part, nous essayons d'incorporer le futur maître dans des séminaires et des colloques. Chaque étudiant avancé a l'obligation, sur quatre semestres d'étude (les deux dernières années) de faire un exposé. Cette «leçon» sera ensuite discutée dans la forme et dans le fond. De tels exercices pratiques sont loin d'être inutiles d'ailleurs même pour ceux qui ne veulent pas faire d'enseignement et que seule tente la recherche scientifique. De plus, comme «assistants-étudiants», les jeunes gens ont la possibilité de participer à l'enseignement pratique. Ils entrent en contact avec des groupes restreints d'étudiants débutants et dirigent leurs exercices de laboratoires. Ces stages aux travaux pratiques sont extrêmement utiles non seulement parce qu'ils permettent d'acquérir, sans peine, des notions fondamentales, mais précisément parce qu'ils obligent les étudiants avancés qui y participent à «enseigner».

Il ne serait pas impossible que soient organisés, dans le cadre des Instituts universitaires de biologie, des cours de perfectionnement, notamment destinés à ces maîtres isolés dans leur collège et trop chargés pour suivre par eux-mêmes les progrès des sciences biologiques. En quelques jours, des enseignements théoriques et pratiques, harmonieusement équilibrés, devraient per-

mettre à ces professeurs de collège et de gymnase de faire le tour des acquisitions récentes et de compléter ainsi rapidement et efficacement leur formation.

7. *Le rôle de l'enseignement des sciences biologiques*

L'enseignement des sciences biologiques – partant de l'observation pure et vivante, passant par l'expérimentation simple et directe, atteignant pour finir la discussion des idées et des méthodes – est un enseignement complet. Il est normal et justifié qu'il figure dans notre enseignement secondaire, et pas en parent pauvre à qui, par charité, on accorde à peine quelques heures. L'étude des formes et des fonctions qui caractérisent le monde vivant apportera aux élèves, préoccupés qu'on le veuille ou non, et surtout dans notre temps, de questions touchant à la vie, une méthode et un bagage. Une *méthode*, et nous en avons suffisamment parlé pour ne plus y revenir, qui, partant de l'observation déductive aboutira à la véritable technique expérimentale et à la discussion critique des faits et des idées. Un *bagage*, qui ne sera pas encyclopédique ; aujourd'hui on a compris que les sciences naturelles n'étaient pas des « sciences exclusivement de mémoire » et les maîtres évitent ces interminables listes de plantes ou d'animaux que les élèves, il y a peu d'années encore, devaient apprendre par cœur. Sans viser à accroître les connaissances, il faudrait les épurer, les limiter à quelques faits essentiels parfaitement assimilés.

Où, mieux que dans *Dialectica*, pouvait-on défendre un tel programme ? Qu'il s'agisse de l'enseignement du collège ou de celui du gymnase, les cours et les travaux pratiques de biologie doivent être une « ouverture » à la science de la vie et des vivants. Cette ouverture vers des *faits nouveaux* et surtout vers une *méthode*, sans cesse remise en question dans le détail de sa réalisation – mais qui reste la même dans ses grandes lignes – n'est-elle pas le propre de toute la démarche méthodologique de F. GONSETH [21] ? Si nous devons formuler l'essentiel de ce nouvel aspect de l'enseignement de la biologie en peu de mots, nous écririons qu'il s'agit avant tout d'un *enseignement dialectique* des sciences de la vie et des vivants.

Plus tard, quelle que soit la direction choisie, le métier envisagé, un tel enseignement aura certainement marqué celui qui l'a reçu. L'étude de la vie échappe en fait à des spécialistes. L'adulte, s'il est curieux, ne pourra pas ignorer les grandes découvertes biologiques qui le concernent directement. Au collège, on se trouve en face du même problème. Et si l'on se limite à l'examen des faits et de quelques courants d'idées, sans entrer dans les explications qui ne sont ni du ressort, ni dans les possibilités de l'enseignement secondaire, l'opposition regrettable entre les « classiques » et les « scientifiques » n'implique pas de différences fondamentales dans l'enseignement de la biologie. Cette biologie-là, ramenée à une *leçon de choses*, à une *leçon de sciences* ou à une

leçon de pensée scientifique n'exige en aucun cas de l'élève une spécialisation initiale. Dans le cadre de l'enseignement supérieur seulement, où les problèmes se posent différemment, la conception de l'enseignement des sciences de la vie changera du tout au tout. L'enseignement secondaire ne vise pas à former des biologistes. Il faut donc que l'élève qui sortira de nos collèges et de nos gymnases possède une connaissance des sciences de la vie assez complète et suffisamment générale. Et si le gymnasien, son bachot en poche, se décide à faire de la biologie, il aura au départ une culture générale suffisante, qui lui permettra d'entrer sans peine dans une spécialité dont il soupçonnait l'existence. Il n'aura pas à se débarrasser, pour repenser les problèmes à une autre échelle, de fausses théories et de faits inutiles.

La biologie est bien une discipline de culture générale, elle doit être enseignée à tous et à tous les degrés. Très justement, L'HÉRITIER et RIZET écrivent [22] «... la biologie est une partie intégrante et essentielle de tout humanisme scientifique. Il importe donc de mettre fin à la situation actuelle où elle intéresse presque exclusivement les naturalistes nés et est considérée avec un certain dédain par les étudiants orientés vers les disciplines physiques et mathématiques. Ceci peut être obtenu à la fois par un choix des matières enseignées et par un changement dans la manière dont elles sont présentées». La biologie d'aujourd'hui est une science expérimentale, plus explicative que descriptive, qui fait appel à la même rigueur et à des raisonnements comparables à ceux de la physique et de la chimie. De plus, les sciences de la vie se trouvent dans une phase d'évolution accélérée; les faits sont constamment remis en question, les données nouvelles s'accumulent avec rapidité et les théories ébauchées présentent un caractère provisoire évident. Dans ces conditions, il est bien difficile d'ébaucher, à l'usage des élèves et des étudiants, une «liste détaillée et définitive» des connaissances à enseigner. Pour cette raison – et pour bien d'autres encore, dont il a été question plus haut – il paraît essentiel d'insister davantage, dans les cours de biologie, sur les méthodes propres à cette science et sur les grands problèmes actuellement à l'étude. Un tel enseignement – essentiellement dialectique, comme on l'a vu plus haut – vieillira moins vite et visera plus à éveiller la curiosité qu'à fournir un bagage fastidieux et trop rapidement inutile.

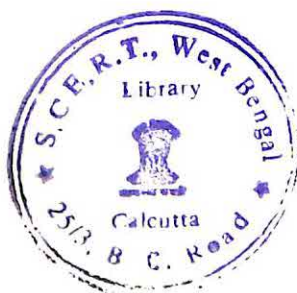
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Hacia una enseñanza nueva de la biología

P.E. Pilet

(Resumen)

El autor señala primeramente la necesidad de presentar en las clases secundarias la nueva imagen de la biología, que no debe reservarse sólo a los especialistas, y a continuación expone el contenido y el espíritu de la biología moderna, como ciencia de la vida, en sus diversos niveles de integración. Se indica además lo que la biología espera de las "ciencias auxiliares". Después de un párrafo dedicado a la biología en la enseñanza universitaria (primaria año), problema que se estudia a la luz de los experimentos realizados en la Facultad de Ciencias de Lausanne, el autor examina detenidamente la enseñanza secundaria.

En los primeros años de esta enseñanza, las "lecciones de cosas" ; descriptivas y de orientación naturalista, deben alimentar la curiosidad de los alumnos y educarlos poco a poco, tanto manualmente como intelectualmente. En cambio, en las clases superiores deben pasar a primer plano las "lecciones de ciencias" sobre los grandes temas biológicos con objeto de desarrollar el pensamiento científico, acompañadas de referencias oportunas a la historia de la ciencia. Con ayuda de ejemplos concretos se hace un minucioso análisis del nivel de las lecciones y de la ejecución de los trabajos prácticos.

El artículo se termina con unas consideraciones sobre la formación del personal docente y sobre la función de la enseñanza de la biología, que para no envejecer debe seguir siendo dialéctica insistir sobre sus métodos peculiares y sobre los grandes problemas que se estudian actualmente.

Introduction to a new method of teaching biology

P.E. Pilet

(Summary)

The author begins by emphasising the need to introduce as early as in secondary schools the new approach to Biology, which should not be reserved solely for specialists. He then explains the content and concept of modern Biology, a life science, at its various levels of integration. He shows what it expects from supporting sciences. After dealing in his first paragraph with the university teaching of Biology (first year), a question which is studied in the light of experiments conducted at the Faculty of Science at Lausanne, he proceeds to discuss secondary education at length.

In the first few years of secondary education, "object-lessons", descriptive and naturalistic in approach, should sustain the pupils' curiosity and gradually bring them on, both manually and intellectually. In the senior classes the emphasis should be on "science-les-

sons" dealing with the major themes of biology and backed up by well-chosen references to the history of science, the aim being to develop a scientific way of thinking. The level of instruction and the conduct of laboratory work are analysed in detail in the light of specific examples.

In conclusion the article examines teacher-training and the role of biology teaching. Such teaching should remain dialectical, in order not to become obsolete, and should stress the methods particular to the science of biology together with the major problems at present under study.

EVALUATION OF BIOLOGY CURRICULA

Hulda Grobman*

The evaluation of each new curriculum or other educational effort is a unique problem. Those who have faced similar tasks may be able to help in suggesting things they themselves have found useful and some of the pitfalls they have encountered. However, each project has its own circumstances and it would be presumptuous of me to hand over a ready-made evaluation program or design, with the implication that this should be accepted by other projects or scholars. Thus, I shall point out some of the problems that the Biological Sciences Curriculum Study (BSCS) and other curriculum projects in the United States have faced, some of the errors that were made, in the hope that this will be helpful in identifying some of the potential choices to be made in your own situation and some of the alternatives available to you. This is not intended as a complete analysis of all the problems or possible facets of evaluation, but rather illustrates some pressing concerns we in the United States have been considering.

In the United States, we are very test conscious; many Americans feel that the word "evaluation" is synonymous with "testing". To define evaluation in this way, is to do an injustice to the curriculum, since tests can touch on only *some* of the aspects of evaluation. To me, the evaluation of a curriculum includes anything relevant to the judgment of whether the curriculum is satisfactory; of whether it is actually implementing the aims of the persons creating it. Thus, in an important sense, the reaction of the writers to keep working on the project is evaluative. Such a decision indicates that they feel that the project continues to have sufficient promise to be worthy of their time and effort. The same may be said about the financial

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supporters of the project. They, too, are evaluating when they continue their financial support. Schools wishing to try out experimental materials are also evaluating, since their participation implies a decision that the materials are worthy of time and effort on the part of school staff and students to work with the project. Schools which improve their laboratory facilities and equipment, after seeing these in use by students in the new curriculum, or which increase the number of hours available for biology or for use of the biology laboratory are making positive evaluative judgments. Such decisions as these are often not deliberately or systematically evaluative, since those involved may not realize that they are making judgments of this nature.

I would suggest that we systematize these and other evaluative decisions and procedures, so that, when we are evaluating, we do it with the full recognition that the decision is evaluative in nature and we base it on the best evidence that can be made available. Such evidence may be of many kinds. At times, it will be students' scores on tests. At other times, it will be judgments of experts in biology, in education, in psychology. By experts, I do not necessarily mean persons with doctoral degrees. A teacher may be an expert, in terms of how materials can be implemented in the classroom. A parent may be an expert, when he mentions that his child is more excited about these materials than about others he has formerly had at school. I use the term "expert" to refer to persons who can give informed opinions about a specific aspect of material. Probably there is no single person who can be expert on all aspects of any given curriculum.

In discussing evaluation, I shall include those systematic judgments which are, in some sense, evaluating the effort involved. This discussion will focus on three questions:

1. What is the aim of the new project or materials?
2. How can we measure success?
3. How can these results be interpreted and used?

1. What is the aim of the new project.

In attempting any kind of evaluation, it is imperative that those concerned with evaluation have an appreciation

of what it is that the project plans to do. Naturally, all of us here are interested in improving biology education. But exactly what is meant when we say "improve biology education" or "prepare better biology education materials", or "have the student understand biology better"? To merely say that I want students to have an understanding of biology does not communicate specific parameters. What I, personally, mean by "understanding of science" is different from what others mean by it, simply because each of us interprets the word "understanding" differently.

Many people feel that doing well on any biology test means that students understand biology. But, unfortunately, all tests do not necessarily reflect the curriculum that you or I would like to see taught. Tests can be built simply to reflect memorization of facts. For example, in biology, one could have a test simply on taxonomic terms. To me, this would not reflect "understanding of biology." I do not mean that students should not learn sufficient terms or facts to be able to handle ideas in biology. But for me, performance on a test of memory would not reflect a major goal of biology education.

One goal of a biology course might be to prepare students for an existing college biology course, or for an existing college entrance examination in biology, in which case a test predicting such success would be useful. Another course might prepare students for a college course, taught the way I think college biology should be taught, rather than the way it is, in fact, taught. I might want to direct my course to the students who will some day be scientists, or to students who will go to college, although not necessarily as science majors. Or I might want to teach all students in the secondary schools. The measure of adequacy of a course directed to any one of these aims might be totally unsuitable for another course with different aims. However, there may be some overlapping of aims; for example, certainly any biology course should present valid ideas in biology, regardless of which students are involved. Thus, a measure of the validity of the biology, as reflected in the reviews by eminent biologists, would be appropriate for any of the above courses. On the other hand,

a test designed for students in one of these courses might be highly inappropriate for those in biology courses with different aims.

In the United States, most 10th grades (15-16 year-olds) take biology.¹ Therefore, the BSCS concerned itself with all 10th grade students. The materials were intended to range in their usability, so that there are some for the extremely gifted student who may one day become a scientist, some for the average and above-average student, and some for the student with an I.Q. of approximately 75-90 on a standard I.Q. (Intelligence Test) scale. The evaluation of BSCS materials has taken these different aims into account. It is my understanding that the Nuffield Foundation materials have been prepared primarily for the more able secondary school student. This is not a matter of one project being better than another, but rather it reflects a basic difference in purpose, a difference that should help determine the kinds of questions asked in the evaluation of each project's materials and the interpretation of the answers given.

There is also a question of what kinds of schools and what kinds of teachers the materials are intended for. The BSCS intended its material for use by teachers who had reasonably sound biology background, but who might need some special additional preparation, both in biology and in the philosophical orientation of the BSCS, before using these materials. In the United States, we have some secondary school teachers of biology whose college programs did not prepare them adequately for the teaching of biology. The BSCS materials are not intended for use by such teachers.

BSCS materials require use of a biology laboratory as an integral part of the program. Some American schools do not have any laboratory, some have laboratory facilities appropriate only for teacher demonstration, or have such limited access to the laboratory (only one or two class periods a week or only 35 minutes a day) that student laboratory work is not feasible. The BSCS materials are

¹In the United States, virtually all 15 year-olds are in school, since the law generally requires school attendance beyond 15 years of age. About 10 per cent of secondary school students attend private schools; these are not necessarily the brightest students.

not written for such schools. They are intended for the majority of the schools in the United States, which should be able to carry on most of the laboratory phases of the program with only small increases in the laboratory equipment.

Even defining the student group and kinds of schools for whom the materials are intended, does not say what a new curriculum is intended to do. One of the BSCS objectives was to prepare students for lives as useful participants in a democratic society, where many public decisions involve considerations relevant to scientific knowledge. This is part of what the BSCS means by "understanding science." To make this still more specific, one can mention tasks students should be able to perform, some of them immediately, some many years hence. For example, when the students are faced with new social problems, today or in the future, they should recognize any scientific implications of the problem, be able to seek out appropriate scientific facts and theories, and use these in arriving at a decision. This should be done without anyone having to tell the student to look for scientific implications related to his secondary school biology course. Thus, the aim is to enable students to use ideas learned in biology in a new context, with the students able to modify their past learning and experience to include new data and theories, and use these as a basis for systematic decision-making. Obviously, the final evaluation of the materials in terms of this goal cannot be made by a test given while the student is in the course, though some relevant information can be gathered during his school career.

A more immediate BSCS aim is to have students use various laboratory instruments with sufficient competence so that appropriate laboratory experiments can be completed. Here the objective is not an end in itself, but rather a pre-requisite for gaining further skills. Given this aim, there would be no point in teaching the use of any scientific instrument that the student would not actually be using in order to achieve a more basic aim. Also, the teaching about the instrument would include only those skills needed to operate it well enough to achieve the satisfactory com-

pletion of the present laboratory work, or of future laboratory work he will probably do.

Another objective of the BSCS is to include the best thinking of current biologists on the broad ideas and general themes or structure of biology today, incorporating the idea that biology is a dynamic and incomplete science, rather than a static science where everything knowable is already known. This does not mean that the past is discarded, but rather that it is taught as a way of understanding how scientific knowledge develops and evolves, with the expectation that today's theories may be challenged and modified in the years to come. Thus, as a new scientific theory is reported in a newspaper, the BSCS would expect students, after having its course, to carefully consider the new ideas, to think through the question of whether they have any validity; if so, in what way the old ideas helped build the new; and what of the old ideas have been replaced and why; and which ones still remain as our current best thinking. All of these expectations are included in what the BSCS means by "understanding biology."

Without such a clear delineation of what it is that the writers want to do, a useful and appropriate evaluation is not feasible. Yet it is unrealistic to expect the writers on a curriculum project, such as the BSCS, to define all their objectives in detail before they start to work. However, it is important for them to keep in mind the need to define these in some specific way, so that those who will use their materials are able to determine whether the materials are accomplishing their purpose. Theoretically, a detailed list of objectives could be defined in advance, but in the experience of a number of our curriculum projects, the more useful specific delimitation of general objectives comes as the writers work with each other and with students and teachers in the classroom, and as they consciously outline the purposes of their work in order to structure the appropriate questions for the evaluation.

2. How can we measure success.

Who should evaluate. At different periods during the curriculum construction, there are different evaluation needs,

and different processes of evaluation are appropriate. Evaluation may be termed as *formative* and *summative*. The *formative evaluation* is that evaluation which takes place during the period in which experimental materials are being constructed, tried out, revised and improved. *Summative evaluation* is the evaluation taking place after the materials are completed.

The major purpose of the formative evaluation is to give information the writers need in order to improve their product. The summative evaluation is the evaluation describing the finished product to potential users, to help them determine whether it will meet their needs, and how it may compare with other products currently available. It is my feeling that much of the formative evaluation must be directed from within the curriculum project itself. This impression is borne out by the experience of several curriculum studies in the United States which tried, unsuccessfully, to have "an objective outsider" do this early evaluation. It was extremely difficult for the project personnel to communicate to such outsiders exactly what it was that they were trying to do. Furthermore, since the evaluative information at this point is for the purpose of helping the writers as they are preparing materials and improving them, it is imperative that these writers have the evaluation information they need, when they need it. An outsider may not be as sensitive to the needs of the curriculum group and to the implications of certain kinds of data. Also, an internal evaluation insures that the writers are satisfied with the criterion measures being used. When the writers, themselves, are responsible for the structure of the evaluation, they will not be inclined to pass off the results as inappropriate. If an outside person or agency is responsible for the evaluation, the writers might well reject the findings on the grounds that the test or other evaluative measure is inappropriate, as it may likely be.

This does not mean that outside agencies cannot help in the formulation of the evaluation, and in the implementation of various phases of the formative evaluation. The BSCS has consistently called in psychometricians to advise and assist in the writing of tests. It has called in reviewers

to help assess the content and approach. But the BSCS found a need for a closer integration of evaluation with curriculum building than was practical with an outside independent agency directing the evaluation.

One may ask, "Is an evaluation really an honest one unless it is done by an independent source?" To assume that it is not, would be to question the honesty of the majority of education research studies and the integrity of professional personnel in academic endeavors.

In the summative evaluation, after the new curriculum materials are completed, there may well be some outside evaluation by others interested in education to determine the worth of the product in terms of their own criteria, which may or may not be the same as those of the authors. For example, an outsider may be concerned with how well the course prepares a student for a particular traditional college program in biology, while the project writers may have been concerned primarily with improving the general educational background of the average adolescent and, in fact, may also believe that traditional college biology needs drastic restructuring. Therefore, the question asked by such an outsider would not be of major concern to the writers. However, the outside evaluator has the obligation to state the context of his evaluation. He should state, not that the materials are "good" or "bad", "appropriate" or "inappropriate", but rather that they are good or bad *according to the particular aim he has in mind*, which may or may not be similar to that of the writers.

During the summative evaluation period, the project itself should continue its own evaluation to determine how the materials are being used, what are the shortcomings, whether additional materials are needed for implementing the curriculum, and whether materials at other levels of the educative process should be revised to reflect the new approach used at this level. In addition, an important evaluation activity is the follow-up evaluation, to determine the extent to which the learnings from the secondary school biology course are retained and used in later years. This, actually, is the crucial test for the curriculum, since no biology course is intended simply for temporary learnings, but

rather for what it contributes to a future educative or other goal of the individual. If the effects of the course are lost after the course is completed at the end of the school year, the fact that during the school year great successes were achieved, is of little importance.

Reviews of materials. There are many ways of evaluating a curriculum in biology. One is determination of whether the curriculum has *construct validity*, that is, does it do what it is intended to do. A course in modern biology that does not incorporate the most recent thinking in biology would *not* have construct validity. A course, intended to emphasize the underlying themes and principles of biology, but actually concerned with detail and memorization would *not* have construct validity.

The determination of construct validity is a value judgment. It is not something one can test for objectively. However, unless some determination is made as to whether the content is actually carrying out the stated objectives, any other type of evaluation is relatively meaningless. What does it matter if the students are able to learn the materials presented if these materials are not related to the aims of the course, or if the biology included is not valid? The determination of construct validity should be made by the writers and by others at the request of the writers. It is also something that outsiders can do independently, *provided they do this in the context of the writers' objectives*. The point here, is not whether the reviewer agrees with the objectives, but are the materials consistent with the authors' objectives. (An outside review of the objectives themselves is certainly worthwhile, but this is a different kind of review and one that may precede or parallel the review for construct validity.) The mere fact that the material was written by the authors does not preclude their reviewing it themselves, with the specific aim of determining whether their aims are implemented. For example, in BSCS, the authors had decided in advance of their writing, that secondary school biology as taught in the United States included too many new terms which were not particularly important, and had too little emphasis on general principles and themes. Yet, after the preliminary editions were pre-

pared, their own systematic check on new terms used in these books indicated that, although relatively fewer appeared than was the case in traditional texts, the number was still too high; as a result, further editing was undertaken.

Other reviews or reactions are in order from psychologists who have studied how children learn, and from educators who are familiar with the abilities of children and with the previous knowledge children bring into the biology classroom. A word of caution is needed, however. In the United States, we find that we cannot predict in advance whether children will be able to handle new levels of sophistication in biology and other fields. We are finding that we can teach some things much earlier, or in a much more sophisticated manner, than had been thought earlier. On the other hand, occasionally experimental materials prepared for the 10th grade biology students were too difficult in the form in which they were originally written. It is for this reason that all BSCS materials were used in at least one, and generally in two, successive experimental editions, in a variety of school situations, before they were made generally available. The materials were truly experimental in that they were sufficiently new and different that it was not possible to tell whether they would succeed until they were actually tried out in the classroom.

Classroom use of experimental materials. A number of important evaluative purposes can be served by trial classroom use of the materials, in part or in total, as the writing and rewriting proceeds. One can test them in the classroom for feasibility to answer the question of whether it is at all possible to teach these materials. If so, what circumstances facilitate the teaching and learning? Is the time limit, in terms of the rest of the course, suitable? Would some adaptations, supplemental materials, or a change in sequence of presentation facilitate learning? Are the learning outcomes the intended ones? Is the teacher's background adequate for the appropriate teaching activities? Would some other approach be more effective in implementing the idea, skill or understanding?

Data for answering such questions can come through reports from teachers, students, parents, school administrators and supervisors; it can come from classroom visits by observers, including the writers and other curriculum project personnel. This is a good way to give the writers, some of them college professors, a better understanding of what is and what is not possible in the secondary school. Tests of various kinds measuring skill, knowledge, broad understandings and the ability to use these in new ways and in unfamiliar situations.

This classroom testing of experimental materials involves such decisions as: how many teachers and students should be involved; how should these be selected; should the teachers receive special training; how shall reports from teachers and others be prepared; what tests shall be used.

Selection of the sample for classroom trial use. A major consideration in selecting the classrooms to participate in experimental use of the materials reflects the purpose of the materials. BSCS materials, which were written for average and above-average students in most American high schools clearly should be tested in situations reflecting such a population. (It might be desirable to use preliminary small-scale tests to determine whether the materials are sufficiently suitable for testing on a wider scale.) Theoretically, one might say that the BSCS should have tested with an accurate cross-section of such schools in the United States. However, while various types of school situations were included in the experimental sample, the BSCS made no attempt to use a representative sample. There are a number of reasons for this.

The BSCS decided to use volunteers for the experimental teaching. It was felt that, unless the participating teacher wanted to explore new ways of teaching biology, the new materials would not have a reasonable opportunity to be evaluated on merit. This was one factor limiting representativeness of sample. Another was the fact that, during several test years, the BSCS asked all test teachers to meet weekly to prepare reports on their classroom experience with BSCS materials. (This was valuable, in that often group reports varied from those submitted by indivi-

duals, in discussing different points, or in offering different suggestions.) These weekly sessions also were valuable as a training device, since teachers could help each other on difficulties and also could share responsibility for obtaining laboratory materials and supplies. However, use of this form of organization required having clusters of teachers in a relatively small geographic area, and so it was a built-in restriction on the sampling process.

Size of sample. The numbers of schools, teachers and students needed for evaluation purposes depends on the kinds of questions to be answered. A relatively small number of classes can provide much information in terms of general feasibility of the materials. For example, for the BSCS second (advanced) high school biology course, the test sample was only 19 teachers and some 500 students, this was adequate for the purposes of this particular evaluation. However, for the basic tenth grade materials, there were three parallel sets of basic materials to be tested, alternate kinds of supplemental materials, and also the problem of what kinds of schools, teachers and students they were most suitable for. Thus, considerably larger samples were required. For the first year of testing, about 100 schools with 12,000 students were included in the initial sample. For the second year, 350 schools with some 50,000 students were included. These are unusually large samples for an educational study. However, given the number of statistical variables to be studied, it was the judgment of research consultants that these numbers were required.

In considering suitable size of test sample, allowances must be made for attrition (loss) in the sample throughout the test year. In the United States, we have a considerable population mobility, so that children may move from one school to another during the course of the school year. The BSCS was concerned with test information only for those students who had been in class all year, since the course materials constitute a full year's work. Thus, students who left before the end of the year, or who joined the class during the course of the school year, were not included in the study.

If, because of some unforeseen accident, the teacher with the students at the start of the year had to be replaced, this entire class was dropped from the study, since all BSCS teachers were given a week of special training (orientation) before the start of the year, and the use of the materials by teachers without such training was not considered suitable for purposes of testing the materials.²

One must also consider the desirability of eliminating classes during the trial year, when, for some reason, full class implementation of the experimental material does not occur. On occasion, despite earlier commitment to fully implement the materials, some BSCS experimental teachers and schools failed to do so. This may happen due to some external reason. For example, in one case, a flood destroyed the supply of books, and the ensuing delay, before the books could be replaced, precluded offering the complete course during that year. Or the reason may be internal to the school.

Use of a control group in testing. Traditionally, in educational experiments, test results of experimental groups are compared with those of control groups, to determine whether there is a difference in relative performance. The BSCS attempted to do this for several years, but found this procedure inappropriate for a variety of reasons. First, there was the problem of contamination of the control group; that is, the control or traditional biology group had been influenced by the BSCS materials and so was not a true control. The BSCS had an active public information program which reflected its obligation to make information on its activities available to the profession and the general public. As a result, it was difficult to find appropriate schools to serve as the control group, since teachers throughout the country were found to have introduced some of the BSCS materials and methods in their classes, even though the material had not yet been generally released for classroom use. Thus, one could not compare BSCS classrooms uncontaminated by BSCS materials and methods.

² Some observers have commented that this orientation of teachers might bias the results; however, since the BSCS considers the method of implementation of materials as important as the written student materials themselves, this training was considered an integral part of the program, and was expected to occur as further teachers adopted the materials in later years.

Some observers have suggested that the same teacher might be asked to teach one or two BSCS classes and one or two classes with traditional materials, thereby providing a control for the experimental classes and eliminating the teacher variable. However, it was felt that this would constitute an unenable burden on the teacher, in terms of doubling his laboratory and classroom preparations. Also, if the method of presenting materials is critical to implementation of BSCS teaching, and the teacher has thoroughly mastered the new method, it is questionable that he could discard it entirely during the hours he is teaching the control class.

From a testing standpoint, where objectives of a new course differ radically from those of earlier courses, *it would appear that the use of a control group for comparison is inappropriate in the formative and possibly in the summative evaluation also.* If the experimental course materials are radically new, what kinds of tests can properly be given both experimental and control groups? In 1961 and 1962, other biology books in the United States had not yet begun to reflect the changes the BSCS was making in content of its curriculum. Thus, to have asked students in the control group questions on homeostasis, for example, would have been futile, since this was not an area covered adequately in their biology course. Yet to fail to ask such questions of BSCS students would have been to ignore a major area of their program.

It can be easily predicted that, on tests reflecting the unique new objectives, the experimental group would do better, and on tests reflecting traditional content not included in the new courses, the control group would excel. However, such a finding would not be relevant to the evaluation of the new materials, since one cannot measure amount of learning in a revised curriculum by using tests that reflect older, discarded values. Such tests can be used in describing differences in learning between two curricula, the old and the new, but this is *not pertinent to the evaluation of the new in terms of whether it is achieving its goals.*

The BSCS is now in the summative evaluation period, and its finding that the problem of contamination of pos-

sible control groups completely precludes any comparison of BSCS learnings with traditional course learnings. Virtually all competing, privately sponsored textbooks issued since 1960 reflect the impact of BSCS to some degree, and possibly as many as half of the biology teachers in the United States have attended some kind of BSCS institute or preparation course. Thus, today, one might consider comparative attainment of BSCS objectives, using BSCS curricula and other current curricula that attempt to parallel or copy BSCS, but, in a very important sense, these latter are not non-BSCS curricula. (This adoption of BSCS ideas and methods by competing curricula, in itself, is a very important facet of the summative evaluation, in view of the BSCS aim of preparing not a "national curriculum," but rather in setting up three models—the Blue, Green and Yellow Versions—of what a good high school curriculum can include and can achieve, with the hope that these would be emulated by others.)

If a control group is not used, how can one measure student achievement of the objectives in a meaningful way? One can measure student standing at the start of the course, during the course, and at the end of the course, along with a description of the teaching situation, and the student activities along the way. It is belaboring the point to question that students would have achieved these objectives without the course, when it is obvious to their teachers and to scientists who see the students coming to college, that this has not occurred in the past. Though the purists may be reluctant to dispense with a control group of some kind, certainly a far more meaningful evaluative result is obtained when the university professor, several years later, finds he must make his first university biology course more sophisticated because his entering students, who have had the experimental course, already possess many of the skills he formerly had to teach.

What tests to use. Unless the criterion measures used to evaluate a product are relevant to the purpose intended, no relevant information can be gained. For example, if one were buying any kind of automotive vehicle, there are a number of common requirements, such as a dependable mo-

tor, good lights, effective brakes, and safe tires, regardless of the use to which the vehicle will be put. But there are also many differences in purposes, which call for different kinds of criteria to assure appropriate performance for a particular purpose. In buying a taxi, a major consideration might be economical operation. In the purchase of a truck there might be different considerations, and even these would not be common for all truck purchases. A truck for local deliveries within Manila, where distances are short and traffic is heavy, there is need for maneuverability, easy parking and an engine that does not overheat with slow driving. A truck for long distance hauling might have very different requirements, including ability to climb mountain roads and traverse rough terrain.

In the same way, all tests to measure a biology curriculum may have some common features. But as course purposes vary, so the evaluative devices to measure accomplishments of these purposes should vary. If the measure is inappropriate, the level of student achievement on such a measure is *not* relevant to the successful achievement of that purpose. Thus, in selecting classroom tests for new biology curricula, it is imperative that the purposes of the course be kept in mind, and that the tests be screened for their consistency with this purpose.

The basic purpose of any education is long-range rather than short-range, and attempts to change the student in some way in preparing him for a future task. This future task may be the taking of another course or series of courses, the handling of a job, or the making of public or private decisions as an adult. Biology, physics, and chemistry are not taught simply for the sake of learnings during that year, to be forgotten after the course-end examination. Our purpose in teaching these and other subjects is in some way to change the student, to give him new understandings, knowledge, and appreciations, behaviors that will be useful, in some way, in the future. Thus, any test we give during such a course, or immediately at its termination, cannot tell us conclusively that the course has been successful in achieving its objectives.

One can hope that, if a student does well on a course-end test, he will use the knowledge and skills later. However, we have found that test achievement in school does not always indicate later ability to use the knowledge and skills in similar and new situations. Our greatest scientists have not always been our highest scoring students in school courses, and many of our highest scoring students have rapidly forgotten their classroom knowledge or been totally unable to use this knowledge in later, relevant situations. Part of our difficulty in predicting ability to creatively use information at a later date may be closely related to the kinds of testing devices we often use in school.

There is a difference between memorizing something, and being able to repeat it in the same or similar words, and being able to utilize this knowledge in a new situation. This difference is increased when the new situation is presented years later. Thus, it would appear important to be sure that the skills we want applied, and the kinds of applications we want made, be presented along with the knowledge, and a check made, *during the course time*, to determine whether this ability has been developed. If it is not currently present, the chance of its being present a decade later is unlikely. We know that isolated knowledge is retained for a shorter period than are integrated, inter-related skills and more general understandings. Knowledge—that is, memorized materials such as facts and principles,—is more likely to be retained when it is learned in a unified context, such as in broad problem-solving, and when the student is deeply ego-involved. (Such ego involvement may occur more readily in a laboratory situation where a student uncovers a principle or relationship himself than in a situation where the teacher tells him of this relationship or shows it to him in a laboratory demonstration.)

In the United States, we generally think of tests as written instruments. We rarely use the formal oral examination at the secondary school level as a testing device, although it is used for informal day-to-day review work. Our written tests may be essay or short answer form, but also are often external tests in an “objective” format. (That is, a relatively brief statement is given and then several

short choices are presented. The student selects from among these choices.)

The BSCS found that, regardless of the type of testing device used—whether oral or written, objective or essay, teacher-made tests generally highlighted isolated knowledge of some sort, memory of facts, terminology, methodology, conventions of science, rather than ability to use this knowledge systematically or creatively in an analytical or evaluative context. Problems to be solved in tests usually closely paralleled those presented in class. There was little demand made on the student to discover what are the non-obvious but familiar scientific elements of a completely new problem, to separate the relevant from the irrelevant, and to synthesize his knowledge of principles, facts, and ideas into a new pattern in arriving at an answer. This was as true for the essay examinations as for the short-answer or objective tests.³

The fault here lies not with the teacher, but with the educational practices which the teacher himself has experienced in his own collegiate training. Often, the tests he himself has taken are memory tests. Also, testing has not been taught to him as a special skill, where the teacher's preparation of the question and decision as to what is appropriate as a correct answer, is far more difficult than the student's taking of the test. (Teachers are so used to knowledge-type tests that, when the BSCS prepared tests intended to measure more than recall of information, teachers often expressed concern that they were not relevant since they were not based directly on the book, a situation which was precisely what the BSCS had intended.)

A further danger in the usual test of memory, is the student's reaction to such tests. When the tests focus on memory alone, the student quickly comes to believe that what is important in the course is memorizing, rather than the principles and underlying themes of biology. Thus, the testing, in itself, may defeat the rest of the teaching activities of the course.

³ In examining test to determine what skills are being demanded of the student, a useful reference is: Benjamin Bloom, Editor, *Taxonomy of Educational Objectives*, New York. David McKay Co., Inc., 1956.

This is not meant to imply that there should be no information memorized or tested. Certainly facts are needed on which to build generalizations and ideas, but these should be kept in proper perspective, rather than being given the major emphasis they now occupy in our teaching and our testing.

In the United States, external subject matter tests in an objective format are available in science and other areas. These are often used in curriculum research to measure student progress. The tests available in 1960, when the BSCS was preparing and trying out curricular materials, reflected the rather classical aims of the traditional courses, and emphasized memory and direct application rather than skills such as analysis of complex situations, synthesis of ideas from many sources and building a new approach from these, evaluating information and sources of information and drawing inferences based on this. Because these tests were not compatible with the BSCS aims, the BSCS felt obliged to prepare its own tests.

In its test-building activities, the BSCS tried systematically to include questions involving the kinds of general skills and understandings it hoped the students would retain and be able to use later, and give practice in their use through the test questions. With tests of this sort, one can still not guarantee that the students who score well on the test will be able to use these skills in such situations later. However, it seems reasonable to assume that this will be a better predictor of high level later performance on similar tasks than would a test of memorized facts and principles.

In test building, it was difficult to explain BSCS purposes sufficiently well to outsiders to permit the latter to build appropriate tests. Yet, writing of tests is a complex skill and one that must be learned. It was at this point that the BSCS intensive test writing sessions, directed by test experts to advise on needed skills. This test writing by the curriculum writers themselves, helped them sharpen their own objectives. For example, in the group examination of a proposed test item, someone inevitably would ask whether this was really what the BSCS meant by

"inquiry", or "understanding photosynthesis", or "creative thinking." And by thinking in terms of the tasks they wanted students to perform, the writers were able to pinpoint objectives and explain them more clearly to others.

The test writing process was also a useful evaluative device for determining gaps in the materials. At times, a test writer would find that the factual orientation of a section might preclude writing anything but a memory question on it. In effect, this was an evaluative judgment of the materials and was taken as evidence that the section in question needed rewriting. Or a writer might think of a highly relevant question—relevant to the aims of the course, that is—but find that the materials omitted the needed background or approach, again indicating a shortcoming of the materials, which were then considered for revision.

There are a number of useful types of tests other than the usual written and oral tests in biology. In the laboratory *performance test*, the student is asked to actually do something in the laboratory, and his process and result are checked. This may be a complex new laboratory problem. Or the laboratory test may be used to determine whether the equipment is being used properly. For example, the student may be asked to use a microscope while the teacher watches, to determine whether the student is able to move his slide properly to bring another area into view. This might be considered a threshold test. In itself it is not important, but without this skill, the student could hardly carry out microscopic investigations. (This skill should be presented to the student as this, rather than as important in itself.) Performance on such a test does not guarantee that the student will use a microscope properly on other occasions, but it is certainly more relevant than asking him to draw a picture of a microscope, label it, and describe its use. The latter type question involves quite a different skill, and one less relevant to the purpose of the BSCS course, that is, the actual use of the microscope to learn more about science.

3. How can evaluation results be interpreted and used.

If information obtained during the evaluation is to be optimally useful, it requires careful interpretation. This interpretation is affected not only by the nature of the evaluation process but also by the timing of the evaluation. For example, during the first year of using BSCS Biology, many teachers reported difficulty in completing the materials. When they used the same materials a second year, they generally reported covering about one quarter more of the course materials. (This experience has been paralleled in other curriculum studies.) Data on testing for successive years appear to support this teacher report, since, the second year a teacher used BSCS materials, his class did better on the BSCS tests than did his previous year's class. Simply on practical grounds, one might hypothesize that, as teachers become more familiar with the new materials and as they have more of the needed laboratory supplies and equipment on hand at the proper time, the effectiveness of the curriculum will increase. Thus, in studying the reactions of teachers and learning of students during the first trial year, one should keep this mitigating aspect clearly in mind.

In reviewing feedback from teachers, it is important to have considerable information on the school and the teacher. Thus, classroom visits are essential. For example, to give proper consideration to a teacher's report that a laboratory exercise is not satisfactory, it is important to know whether the problem might lie not with the adequacy of the exercise, but rather with the inadequacy of the facilities and equipment available for carrying it out. It is also important to know whether the teachers are, in fact, teaching the new curriculum or merely using new books along with old lecture notes and methods; such a procedure would not constitute a realistic or reliable, trial of the new materials.

The nature of the classroom presentation can be a major influence on the evaluative data received, and without a classroom visit, one could not be aware of these limitations. For example, in one classroom in the BSCS evaluation, when one youngster questioned the answer given as correct on an examination, he was told, "Your answer is wrong because that isn't what the book says." The BSCS cur-

riculum is intended to stress creativity, encouraging the student to bring the experience to bear on new situations; but this unfortunate teacher stressed a different and antithetical process. Thus, when the evaluator later looks for in class visits, the students will probably implement the type of behavior they have been rewarded for previously, that is, conformity. When the evaluator does not find the desired results, where does the fault lie? He needs enough information about the teaching process in this experimental classroom to be able to interpret his data adequately.

To strengthen confidence in the interpretation of evaluative data, it is useful to have a number of sources or instruments to rely on. Multiple approaches may save an entire evaluation program if a particular scheduled test, visit or review becomes impossible, since there would be others on which to rely. Also, the very tests built into the evaluation are themselves being evaluated. They, too, are still in the formative stages since they must be developed concurrently with the curriculum. Thus, the tests may be far from the precise measuring instruments desired for accurate evaluation. However, imperfect as they may be, if we have data from several sources all tending in the same direction, we have better grounds for making evaluative judgments and reaching conclusions.

In considering the evaluation of the new curriculum, it is extremely important to assure those involved that *this is not an evaluation of the teachers who are helping to test the materials*. The task clearly is one of evaluating materials and not teachers, and unless everyone participating clearly understand this, there may be serious problems in achieving full teacher cooperation; in establishing comfortable and representative situations while visiting classrooms; and in receiving useful and honest reports from the teachers. Even student test records may be biased, if the teacher feels that these tests are used as a gauge of his teaching ability rather than as an indication of the worth of the materials. The entire validity of the test results may be jeopardized if the teacher feels that he himself is on trial, and that his students must show up well on the test.

Regardless of the merit of any new course, *one must expect only modest measurable changes to occur in students during a single year*, and the sponsors should not be disappointed with small gains. This may be difficult idea to accept, when the proponents are convinced that the course is quite revolutionary in approach and content, and that the result should be equally revolutionary. In the United States, for example, the student is with the biology teacher only an hour or less a day, for only one school year. This really provides a very limited contact and human beings change very slowly. In important matters, such as ways of thinking, people change more slowly than in the relatively less important areas, such as acquisition of facts. And the other activities of the school and the society may not yet be supporting the desired change with consistent expectations. For example, in BSCS Biology, there has been a stress on developing an inquiring mind, on developing creativity. Not only is it difficult for the biology teacher to act consistently with this objective (since creativity could delay class completion of work) but other areas in the school may be stressing conformity of thinking. Yet the aim of the new curriculum in biology is not simply creative thinking in biology, or in the biology classroom, but rather the development of a way of thinking for use in later life. The best way to demonstrate to students that creative thinking is a desired behavior is to be consistent in this demonstration.

Let me illustrate this: one day, a BSCS teacher expressed concern with the fact that some of her best students were having great difficulty in their English classes. Further discussion indicated that the biology teacher had been encouraging a questioning attitude indicating that nothing should be accepted simply because it is stated authoritatively and, rather, one should ask the reasons why. These students were carrying this learning over to the English class and were asking the English teacher for reasons behind her statements. And the English teacher resented this questioning of her authority. Through a trial and error process, these students learned that in the biology class one should ask, "why?" but in certain other situations it was advisable to accept authority without question. Such learning was

defeating the basic purpose of the biology course, that is, to develop an inquiring attitude toward all phenomena.

Thus, it may be that one cannot expect student performance to reflect the new thrust in a biology course until there are parallel new thrusts in other curricula consistently throughout the school and college years. In many countries, there is already a diffusion of many of the ideas in the new secondary school science courses into science courses at other school and college levels and also into other academic areas including mathematics, the social sciences and the humanities. As these efforts grow, our success in the new biology will be reinforced and enhanced.

Evaluation of Biology Curricula

H. Grobman

(Résumé)

La mise au point d'un nouveau programme d'études comme celui du BSCS, demande avant son adoption définitive l'étude des trois points suivants :

1) Buts du nouveau projet

- en premier lieu préparer les jeunes à vivre en homme compétent dans une société démocratique qui intègre de plus en plus les données scientifiques dans ses décisions ;
- permettre aux étudiants d'utiliser convenablement les instruments mis à leur disposition ;
- faire assimiler la pensée des biologistes actuels.

2) Mise à l'épreuve du projet

- au moment de la conception du programme : les auteurs sont seuls à intervenir et utilisent les informations qui leur sont données ;
- lors des essais de diffusion : un échantillonnage le plus représentatif possible de l'ensemble de la population doit permettre la mise à l'épreuve du projet. Ces essais consistent à juger de l'opportunité du matériel proposé et ceci suivant les divers niveaux scolaires ou conditions matérielles.

Tout au long de cette épreuve, des comparaisons ont lieu avec un groupe témoin également représentatif et dans la perspective du but final fixé par le BSCS.

3) Interprétation des résultats

Il faut tenir compte avant tout de la variabilité des résultats. Le temps estompe les échecs partiels du début et joue en faveur de l'expérience tentée.

Evaluación de los planes de estudio de biología

H. Grobman

(Resumen)

La preparación de un nuevo programa de estudio como el del BSCS, exige antes de su adopción definitiva el examen de los tres puntos siguiente:

1) Fines del nuevo proyecto

- en primer lugar preparar a los jóvenes a vivir como hombres competentes en una sociedad democrática que integra cada vez más los datos científicos en sus decisiones;
- permitir a los estudiantes utilizar convenientemente los instrumentos puestos a su disposición;
- hacer asimilar el pensamiento de los biólogos actuales.

2) Prueba del proyecto

- en el momento de la concepción del programa: los autores son los únicos que intervienen y utilizan las informaciones que se les proporcionan;
- durante los ensayos de difusión: un muestreo lo más representativo posible del conjunto de la población debe permitir la prueba del proyecto. Esos ensayos consisten en evaluar la adecuación del material propuesto en los diversos niveles escolares o condiciones materiales.

A lo largo de esta prueba se hacen comparaciones con un grupo testigo que sea también representativo y teniendo en cuenta el objetivo final asignado por el BSCS.

3) Interpretación de los resultados

Hay que tener en cuenta ante todo la variabilidad de los resultados. El tiempo atenúa los fracasos parciales del comienzo y favorece el experimento emprendido.

THE RELATION OF SCHOOL BIOLOGY TO POST-SCHOOL BIOLOGY AND EVERYDAY LIFE

V. Basnayake and H. Crusz*

In the Southeast Asian Utopia of Pala (1) the potentially intimate relationship between biology and everyday life was transformed into actuality. A Rothamsted-in-the-Tropics had been instrumental in making Pala self-sufficient for its food supplies. Research was focused upon the sciences of life and mind. There was fertility control, and A.I. was commonly practised with the deliberate intention of improving the Palanese stock. The problem of power was dealt with not only at the legal and social level but also at the physiological level. The school curriculum included physiology and psychology. Verbal education in these and other subjects was balanced by training in the art of not taking words too seriously. ("Birds aren't words, birds are real") and by training in the art of perception and non-verbal experience. From infancy children were conditioned to love animals; animal pets included not only dogs but lizards and pythons as well. At 4-1/2 years of age, the Palanese child was examined by means of a battery of tests which included somatotyping, psychological tests, radiographs, EEG and biochemical tests, in order to ascertain the psychophysical group to which he belonged. The subsequent education of the child took account of these findings about its individual characteristics.

We who belong to the less ethereal parts of Southeast Asia can also speak of some degree of enrichment of our human lives which we owe to the work of biologists, but we also know that there still remain enormous gaps between biology and everyday life. The control of malaria has been one of the biggest achievements. In Ceylon, malaria was one of the commonest diseases up to the nineteen

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forties. Once in 4-6 years there used to be an enormous increase in the number of cases of malaria. The worst of these epidemics on record was in 1934-35. In 1935 there were 4 million case visits to hospitals and 60,000 deaths from malaria. In 1945, DDT was first used for malaria control in Ceylon. The results were dramatic. Continued efforts have made malaria a rare disease in present-day Ceylon, and the economic development of the extensive zones of country that were once malarial is now taking place rapidly. As a result of malaria control as well as of other advances in medical biology, death rates are falling. The death rate in Ceylon in 1945 was 21.9 per 1,000 population; by 1961 it had fallen to 8.0. In food production, rice yields are being improved as the result of the work of biologists who have developed fertilizer-mixtures, high-yielding varieties of paddy, and the control of weeds and insect pests. But now, look at the gaps that still exist between biology and the everyday life of Southeast Asia. Is there a need to control the growth in numbers of our human population, and have control measures been effectively instituted? Do our people get enough to eat? How much further have we to go before we can speak of the conquest of undernutrition and malnutrition? Have our people got houses designed for physiological health and for thermal comfort in our hot climates? Have our people learned to avoid the misery of preventable diseases? Are we conserving our natural resources to the best of our knowledge and ability?

Should school biology concern itself with the connections and the gaps that exist between biological knowledge and the application of this knowledge to the everyday life of the nation? It is generally accepted that school education is meant to prepare the pupils for "life" and "citizenship." In the case of certain subjects, like economics and civics, school teaching tends to be primarily geared to national conditions rather than to conditions in the world at large. Certain other subjects, like foreign languages and music, are relatively autonomous and the syllabuses for these subjects may be much the same in different parts of the world. With regard to history, most nations would

support the idea that school pupils should learn the history of their own country plus or minus world history. When it comes to school science, agreement is less general among educators as to whether the relationship of science to everyday life should be explicitly taught. Biological educators disagree among themselves about the desirability of including "applied" biology in the school biology course. "Applied biology" has been called "second class biology" (2), implying the existence of castes in the content areas of science courses. The cry in today's science teaching is "Inquiry." But is there no "inquiry" in applied biology? The *BSCS Yellow Version* opens with an account of the conquest of malaria, a conquest which it regards as a grand example of biological investigation (with humanistic overtones). The *Blue Version* deals with selective breeding. The *Green Version* discusses agricultural biology and wildlife management. Indeed the last chapter in this version is on Man and the Biosphere, and the aim of the chapter is to look at topics that will concern the pupil in the future as a citizen—topics which go beyond biology into other areas of knowledge (3). All three versions at the trial stage dealt with the topic of immunization against bacterial disease (the *Blue Version* discarded it in the public edition). One of the aims of the Nuffield Biology Project is "to give an idea of the usefulness and social implications of biology in relation to man's everyday needs, e.g., food, public health" (4). It will be seen therefore that applied biology is by no means wanting in the course contents of the two contemporary giants in school biology, curriculum revision, the BSCS and the NBP. Criticisms of "applied biology" often turn out to be criticisms of teaching methods (such as the mere telling of masses of facts to the pupils, chalk-talk, the enunciation of dogmatic rules of health) rather than of applied biology *per se*. It is a case of mistaken identity: bad pedagogy of the applications of biology has been wrongly labelled "applied biology." Even the great ones can fall into the trap of misuse of terms, and even the term "biology" is not exempt: Sir Ronald Ross wrote in his memoirs in 1923, "I could go back there (Calcutta) tomorrow and start the work again exactly as I left it 23 years ago—not biology, but real measured science." (5). It can be argued that the

distinction between "pure" and "applied" biology is not always clear and not generally desirable, but we need not enter into that argument here. Biology is amphibious—Nehru (6) once cited the line:

*"Lord, though I live on earth, the child of earth,
yet, I was fathered by the starry sky."*

Biology is concerned with the origin of life as well as with the origination of new varieties of food crops; the enzymology of epidermal regeneration as well as the function of clothing; the nesting habits of birds as well as the effects of air-conditioning upon human efficiency. Pure and applied aspects of biology are not mutually exclusive; they are complementary. Both are necessary for our welfare. The creator of Pala also wrote an essay called *The Education of an Amphibian*, in which he says, "Every human being is an amphibian—or, to be more accurate, every human being is five or six amphibians rolled into one. Simultaneously or alternately, we inhabit many different and even incommensurable universes." (7). Palanese superiority lay not in symbolic expression but in "an art, which though higher and far more valuable than all the rest, could be practised by everyone—the art of adequately experiencing, the art of becoming more intimately acquainted with all the worlds that, as human beings, we find ourselves inhabiting." We desire to appreciate the intellectual as well as the utilitarian value of biology. We desire to appreciate science "both as a process of discovery and as an influence on human welfare" (8). For developing countries in Asia, however, practical applications of biology are their very life blood and must be inculcated as early as possible in the educational process. It is ironical that in Asian countries where biological factors are so closely linked with their existence and survival, the teaching of biology in schools and universities has for a long time been too academic or rather, too textbookish—in fact, foreign-textbookish—neglecting its practical aspects and its essential role in national development. There are, no doubt, historical reasons for this, but it has got to be corrected.

One of the first big problems facing a curriculum revision group is the choice of the content area that is to be

taught. The length of the school biology course varies in different educational systems from one to six years or more. We are using the term "school biology course" to mean a course which deals with the *ideas* of biology at school level. We would therefore not consider such biological activities in the elementary school as nature study and gardening, as biology. In Pala, even the youngest children in school played biological games like Evolutionary Snakes and Ladders and Mendelian Happy Families. This is all very well. But biology itself is essentially a set of concepts about living things, and its study requires a degree of maturity which is usually taken to be found in children who are well over 10 years of age. The school biology course in Ceylon at present lasts two years at GCE Ordinary Level (14 + to 16 + years) and a further two years at GCE Advanced Level. Only about 18% of the population of pupils at GCE OL study science, and in most cases the science subjects they study are biology, chemistry and physics. For the great majority of these pupils, the two years of Ordinary Level school biology constitute the only period during which they will be taught any biology at all. What biology should we teach them during these two years? The old Rajah's mynahs flew all over Pala parroting wisdoms which were beyond the powers of understanding of a bird brain: "Attention", "Karuna" and "Here and Now, boys." Our biology teaching is for the here and now—the Southeast Asia, or the Ceylon, of the present day, and not for the brave new world of the future. Given a two-year course which is terminal for most of the pupils, we have to make our choice of content area.

Let us put it in the form of a series of questions. If you had to advise in a case where a choice had to be made between teaching that carbon monoxide inactivates haemoglobin and teaching that the chief causes of anaemia in a South East Asian country are malnutrition and hookworm, which would you recommend for teaching 15-year-old pupils in the country's schools? Most of the pupils will have no further education in biology (except self-education). If you had to advise a choice between teaching that biologists have made interesting speculations

about the food webs in dinosaur times and teaching that it is possible to devise formulae for a cheap and nutritious diet for the people which would you recommend for teaching 15-year-olds in the Southeast Asian schools? What is the choice between teaching that the study of courtship behaviour in the stickleback has shed light upon the nature of instinctive reactions, and teaching that several socially acceptable methods are known which can control reproduction? What is the choice between teaching that the photosynthetic process can be divided into light and dark reactions, and teaching that the biological effects of "light" include photosynthesis, vitamin synthesis, destruction of microorganisms, etc? That inland waters can be used to culture food fish, or that life in the ocean depths shows many strange adaptive peculiarities? That the pattern of life in Palaeozoic waters underwent big evolutionary changes, or that the patterns of disease are changing due mostly to the application of recent advances in preventive and curative medicine? That there are six great realms in the geographical distribution of animals, or that the main agricultural crops in the country are mostly plants which have been introduced from abroad? That harmful biological effects of ionizing radiations include radiation sickness, tumors, leukaemia and undesirable mutations, or that biologists have made interesting guesses about the origin of life? That animal populations show fluctuations which may be due to density-dependent factors, or that useful measurements of the health of a population include death rate, infant mortality rate, birth rate and expectation of life at birth? That artificial selection and hybridization are important methods of establishing high-yielding and disease-resistant varieties of plants and animals, or that the Hardy-Weinberg principle is a quantitative statement showing that the characteristics of a population of organisms tend to remain stable from generation to generation? That three primary germ layers are recognizable in the development of the higher animals including the higher invertebrates, or that external agents such as drugs and x-rays can affect developmental and regenerative processes? That the major land biomes include tundra, taiga, deciduous forests, rain forests, etc., or that it is desirable to preserve certain tracts

of natural forests from encroachment by man? That a paddy field is an artificial ecological community, or that biologists have made interesting guesses about the ecology of Mesozoic times?

In short, we take the view that school biology in Southeast Asia should deliberately aim at helping the pupils to recognize that there are connections between biology and human welfare, and that only some of these connections have been bridged as yet. We hope that the biology teaching which flows from such an aim will help bring about the development of a citizenry which will facilitate the future bridging of the gaps existing between biology and human welfare in our countries.

Let us turn to the other subject of this paper, namely the relation between school biology and post-school biology. By post-school biology we mean biology required for certain professions and vocations like medicine, agriculture and horticulture, veterinary science, fisheries, forestry, nature conservation, wildlife management, the scientific administrative service (in agricultural and fisheries departments and in natural history museums, botanic gardens and zoos), biological industries (tea, rubber, coconut, pest control, etc.), teaching in schools and teacher-training colleges, and teaching and research in universities, technical colleges and agricultural colleges and institutes. All these fields need professionally qualified biologists, generally with university degrees, and biological technicians. We think it important also not to lose sight of another category, namely the amateur biologist who pursues the study of biology for the sheer love of it and more often than not, enriches some aspect of the subject with contributions of real value.

As indicated earlier, only a relatively small proportion of our Ordinary Level (14- to 16- year-old) biology pupils continue biological studies in a specialized way at a later stage. In Ceylon, of every 100 Ordinary Level pupils who learn science subjects (including biology) about 20 proceed to the Advanced Level in school. Of these 20, about 5 succeed in going on to higher education in the universities and technical colleges, and only 1 of them in respect of biology or related fields such as medicine.

Meagre though the numbers are of persons trained in post-school biology, the available employment opportunities tend to be even more restricted. The pupils who are being trained in school for post-school biological studies, which by and large mean university biology, far outnumber the employment opportunities in this field. Pure economics alone may suggest that the education coat should be cut according to the cloth of manpower requirements. Free general education for everybody is said to lead to the vicious social problem labelled "the educated unemployed"(9). On the one hand, the coffers of education have limited funds, and mass general education is accused of giving rise to mass unemployment. As Phillips put it, "The evidence is that few countries hitherto have placed, at any rate in their policy decisions, emphasis upon the role of education in manpower or human resource formation in the economic or occupation sense"(10). On the other hand, manpower requirements are not the only consideration in a question as to why a nation spends so much money on the education of its people. There are cultural considerations, too (11). Educational policy has to be steered between the demands of pure economics and of pure culture. This is a difficult problem indeed for Southeast Asian countries.

Must school biology for the majority who are not going on to further biological studies be different from school biology for the minority who are proceeding to post-school biology? We are inclined to think that more than one answer is possible here, especially with regard to Advanced Level school biology. However, we favour the opinion that school biology should deal with a wide range of the general ideas of biology. This is not a case of "pure" versus "applied" biology. It will be agreed that the general ideas of biology can at least sometimes be taught in an applied context. Amphibiously, we are in favour of trying to make pupils appreciate "the nature of biology, its modes of inquiry, its major theories and conceptual inventions(12), and at the same time, use, as raw material for teaching all this, as much as possible of the facts and problems immediately connected with the country's welfare. If this could be done, and we believe it could, then there is no need for a dichotomy.

tomy of interests and approaches, particularly at the Ordinary Level stage of school biology teaching or even later in school education. The universities and other bodies will have to so adjust their entrance requirements and testing as to conform to such a new orientation.

There are difficulties to be faced. Like Western Nigeria(13), Southeast Asian countries have their share of factors blocking progress in this direction. For instance, although we in Ceylon have our own examinations (still modelled on those of the West), we have been depending largely on foreign textbooks for biology teaching in schools and universities. Not so long ago, however, in 1938, there was in Ceylon a professor of Zoology, a foreigner, who insisted on referring to local animals in the course of his teaching, but the students reacted to this generally with a stamping of feet. There has been a failure on our part to gear our teaching to agriculture, public health and the economic development of the country. And there is the subtle influence of tradition, if not of a positively superstitious environment, working against us all the time. When the Puffin book on the *Human Body* was translated into Sinhalese(14), certain illustrations of the original English edition were subjected to fig-leaf treatment by the publishers in deference to tradition. The traditional respect for the guru, and the mentality it engenders, have made pupils depend more on the authority of the spoken and written word than on their own powers of observation and critical thinking.

Is there not a case, therefore, for each country to develop its own materials for biological education in the light of its own problems and its own conception of what the proper balance should be between such things as "scientific method" and "mere facts" and between "pure biology" and "applied biology"? We believe that the last word on the content of a Universal Biology has not yet been spoken.

ERRATA SHEET FOR THE PROCEEDINGS OF THE FIRST ASIAN
CONFERENCE ON SCHOOL BIOLOGY DECEMBER 1966

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The relation of School Biology to Post-School and Everyday Life

V. Basnayake and H. Crusz

(Résumé)

C'est aux travaux des Biologistes que l'on doit certaines améliorations des conditions d'existence (contrôle de la Malaria par ex.), mais il n'en est pas moins vrai que d'énormes fossés séparent encore la Biologie de la vie quotidienne en Asie du Sud-Est (lutte contre la faim, mauvais équilibre alimentaire).

L'enseignement de la Biologie tel qu'il se pratique dans les écoles doit-il ou non tenir compte des rapports qui existent entre la science et la vie quotidienne : la Biologie appliquée ne devrait-elle pas être considérée comme sujet d'études scolaires au même titre que la Biologie fondamentale ?

Dans l'Asie du Sud-Est, où les facteurs biologiques se trouvent étroitement liés aux conditions de vie, les applications pratiques doivent être aussitôt que possible incluses dans les programmes d'éducation.

Au niveau du secondaire, l'enseignement devrait viser à informer les élèves des rapports existant entre la Biologie et la prospérité générale de leur pays. Mais l'enseignement dispensé doit-il varier suivant qu'il s'adresse à des élèves destinés à abandonner toute étude de Biologie une fois terminées leurs études secondaires ou bien à la minorité de ceux qui plus tard poursuivront ces études en vue de devenir médecins, vétérinaires, agronomes, chercheurs ou professeurs.

L'idéal serait un enseignement de Biologie fondamentale (nature et méthode de recherches) qui trouverait son illustration dans des faits directement liés à la prospérité du pays.

Chaque pays disposerait ainsi de ses données d'enseignement personnelles.

La relación entre la enseñanza de la biología y la vida postescolar y cotidiana

V. Basnayake y H. Crusz

(Resumen)

Aunque los trabajos de los biólogos han permitido ciertas mejoras en las condiciones de existencia (reducción del paludismo, por ejemplo), no es menos cierto que en Asia Sudoriental hay todavía una enorme separación entre la biología y la vida cotidiana (lucha contra el hambre, desequilibrio alimentario).

Cabe preguntarse si la enseñanza de la biología, tal como se practica en las escuelas, debe o no tener en cuenta las relaciones que existen entre la ciencia y la vida cotidiana, y si la biología aplicada no debería considerarse como un tema de los estudios escolares con la misma razón que la biología fundamental.

En Asia Sudoriental, donde los factores biológicos están estrechamente ligados a las condiciones de vida, las aplicaciones prácticas deben incluirse lo antes posible en los programas de educación.

En el nivel secundario, la enseñanza debe tender a informar a los alumnos de las relaciones existentes entre la biología y la prosperidad general de su país. Sin embargo, la enseñanza dispensada debe variar según que se destine a los alumnos que abandonarán el estudio de la biología al terminar la escuela secundaria o a la minoría de los que proseguirán ulteriormente esos estudios para hacerse médicos, veterinarios, agrónomos, investigadores o profesores.

El ideal sería una enseñanza de biología fundamental (naturaleza y método de investigación) ilustrada con los hechos directamente ligados a la prosperidad del país.

Cada país dispondría así de sus bases de enseñanza particulares.

THE SOCIAL RESPONSIBILITY OF THE BIOLOGY PROFESSOR

The responsibility—or lack of it—of the professor to make students aware of biology's social implications proved to be a point on which virtually everyone had strong opinions. It was suggested, for example, that the study of genetics include discussions of race, or the study of ecology include discussions of man's need to control his birthrate.

One participant wrote strongly in favor of the professor's responsibility to emphasize the social implications of science in general, and biology in particular:

The purpose of our schools is the development of free, capable, and responsible individuals aware of something beyond their desks or benches . . . within themselves, within their homes, within their society, and ultimately, within the nature of the universe. At the heart of our system of higher education is the liberal arts college. It is here that we expect our future leaders to acquire the perspective, the

insight, and the ability to communicate that will enable them to become the catalyzers and the binders of an open society. The teacher of undergraduates must therefore be more than a specialized scholar; he must himself possess the general skills and exemplify the values he is responsible for transmitting. There will always be those who will not acquire a wider view and sense of responsibility commensurate with their achievement in specialized tasks, and there will be those who do not have the ability or the will to achieve mastery in some endeavor, but an increasingly high proportion of the educated must possess both breadth and depth if we are to avoid being ruled by technicians and demagogues.

Later in his paper, he stated:

The massive involvement of science in our lives has forced upon the scientist a new responsibility, both as an expert and as a citizen. The scientist can no longer feel that the essential amorality of science absolves him from responsibility for the uses of technological power. He has become a new keeper of mysteries. Rather than act merely as an oracle, he must learn to communicate to the non-scientist the essential implications of his methods and findings; at the same time he must not assume that his technical competence makes him infallible on questions beyond the realm of science.

Another participant, also in favor of a strong "responsibility" stand, noted our "capacity to release more energy and cause more change in nature per unit time than man has ever known." He felt that such power must carry with it full recognition of man's responsibility to himself and his land "for the management of the changes he chooses to introduce."

Human values, felt by some to be inherent in a biology course, were also of concern. One person felt that biology, as well as the humanities, must give the student the "basis for rational decision-making in his future life" and the realization that "his life is shaped by decisions which are rooted both in concepts of science and religion, law, art, etc." Another participant stated this idea another way:

I also think that a liberal education course in biology should recognize that man has a rightful interest in himself as a biological organism. I do not propose that this become a "human centered" course; on the other hand, I feel there

is an obligation of biology teachers to see that the student obtains a concept of himself as a biological organism and a part of the living world. There is also an obligation to point out ways in which biological facts and concepts are involved in medicine and in social and political problems.

Conversely, many felt that a biology professor should *not* concern himself with the social implications of his subject. Outspoken in this matter was Dr. Paul Weiss, of the Yale University Department of Philosophy. He felt emphatically that the biology instructor's only responsibility was to teach good, up-to-date biology, and that the constant attempt to show utilitarian justification for a particular area of biology was, in a very real sense, an attempt to justify its existence—to "apologize" for it, so to speak. Other participants, echoing this view, believed that such an approach worked against a primary educational need of the non-science major, i.e., the imparting of an appreciation for pure or basic research, with no eye to the ultimate usefulness of the knowledge such research might bring:

An introductory biology course can serve the general student in another area of human endeavor where topics in biology impinge on problems in man's society. Ever since the explosion of the first atomic bomb 20 years ago, the question of the social implications of science and the role of scientists as professionals should play in the solution of social problems has been discussed and debated. As responsible biologists, it is incumbent upon biology teachers to present to the students in an unbiased manner the facts and their scientific bases, pointing out their inadequacies and incompleteness where they exist. Problems that appear imminent should be indicated whenever they are relevant to a particular topic under consideration. But presentation of personal opinions and decisions for social action are outside the scope of biological education.

Pragmatic matters such as natural resources, moral issues such as freedom, equality, regulation of the individual, high human virtues such as a sensitivity to beauty, and humility, are capable of deriving a part of their essence from an awareness of biological principles. I do not think that repetitious exhortations or charges to the audience are the means by which the implications of biology are brought to the student's awareness. I strongly believe that the role of the biologist in a liberal education is to give the student good biology.

An interesting sidelight of this discussion was the distribution of mimeographed copies of taped interviews between one biology professor and a few of his students. Part of the discussion concerned the students' opinions on the desirability of professors connecting the subject matter with its possible social significance. The opinion was fairly unanimous among these students that they did *not* want the two related for them. Of particular interest here was the fact that these students were from an institution noted for the student body's involvement in humanitarian and social-responsibility movements.

While there was sharp disagreement on this matter initially, I think that both sides saw and agreed with the concerns of the other. Those who believed in the biology professor's obligation to establish the social implications of his discipline seemed to reflect the concern for the bridge between the "two cultures." Those opposed did not lack this concern; rather, they feared that the professor's zeal to relate biology to contemporary problems of mankind might cause him to propagandize in favor of one particular political or sociological bias—to impart opinions which were less likely to have been scientifically derived. It was pointed out that while genetics might be used to help promote racial harmony, it was also used by Nazi Germany to promote just the opposite.

In conclusion, most seemed to agree that the manner in which the social implications of biology are introduced into the classroom is of considerable importance. Where it is appropriate to illustrate a biological principle, they concluded, certain sociological problems have a rightful place in the classroom. Twisted to fit an individual professor's bias, however, such problems have no place at all in a biology course.

The Social Responsibility of the Biology Professor

Cuebs Publication

(Résumé)

Devant les implications sociales de la Biologie, les opinions quant au rôle du professeur chargé de son enseignement sont divergentes ; certains voudraient que les Biologistes aient une responsabilité accrue tant comme expert que comme citoyen et qu'ils forment leurs élèves dans cette optique.

D'autres au contraire (certains étudiants notamment), estiment que le professeur ne saurait avoir d'autre but qu'un enseignement des seuls faits biologiques.

Tous admettent en revanche l'importance du problème posé : celui de savoir quelle place il convient de réserver aux implications sociales dans l'enseignement de la Biologie. Il est normal que certains problèmes sociologiques soient signalés en classe, pour autant toutefois que ceux-ci ne soient pas le prétexte d'injustifiables interventions personnelles.

La Función Social del Profesor de Biología

Cuebs Publication

(Resumen)

Ante las repercusiones sociales de la biología, las opiniones sobre la función del profesor encargado de su enseñanza son divergentes ; algunos querrían que los biólogos tuviesen una función mas amplia, no sólo como expertos sino también como ciudadanos, y que formasen a sus alumnos en esa perspectiva.

Otros, por el contrario (sobre todo ciertos estudiantes), estiman que el profesor no debe tener más misión que la enseñanza de los meros hechos biológicos.

Todos admiten, en cambio, la importancia del problema planteado : determinar qué lugar debe reservarse a las consecuencias sociales en la enseñanza de la biología. Es normal que ciertos problemas sociológicos se mencionen en clase, siempre que no sirvan de pretexto para injustificables intervenciones personales.

Section 2 / Partie 2

INDIVIDUAL DISCIPLINES / DISCIPLINES PARTICULIERES

From molecules to organic diversity

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THE WORDS CHEMISTRY and evolution, when used together, tend to evoke a very specific image in our minds. It includes questions about the origin of life, about the primacy of heterotrophism over autotrophism, at what stage nucleic acids entered the picture, the shift from anaerobic to aerobic pathways, and many related topics discussed in numerous recent symposia.

What fascinates me about the mentioned evolutionary steps is that they all occurred so relatively soon after the origin of life. The vast majority of the kind of molecules and macromolecules that are of primary importance in living organisms, and of the chemical pathways that lead either to more complex molecules or to their breakdown, exist already among the bacteria.

Since these questions have been abundantly discussed in many symposia, I want to concentrate on biochemical evolution in higher organisms. I am particularly concerned with what seems to me to be one of the great paradoxes of nature: the contrast between the essential chemical unity of organisms from the lowest bacteria to the highest animals and plants, with the truly staggering diversity of life on land, in water, and in the air. To what extent can we hope to explain the evolution of this diversity in terms of chemical evolution? What role has chemical evolution played in the evolution of this diversity?

I hardly need to stress to this audience the extraordinary uniformity of life, not only in its cellular constituents but also in its chemical components and metabolic pathways. Whether we deal with information transfer through precisely replicating nucleic acids, or the role and nature of enzymes, or energy transfer through ADP and ATP, the unity of life from bacteria and viruses to the higher animals and plants is astounding. As far back as the simplest of all free living organisms, the eubacteria, we find that they are metabolically complete. Energy transfer by polyphosphates, information transfer through nucleic acids, protein formation, catalysis through enzymes, all that is already present to perfection.

In order to bring the magnitude of our problem into sharper focus, let us have a quick look at organic diversity, the extent of which only the specialist in zoology and botany can fully appreciate. We find astounding diversity even at the level of unicellular organisms, viruses, rickettsias, bacteria of all sorts, blue-green algae,

innumerable kinds of fungi, regular algae, and protozoans. The diversity becomes even more overwhelming when we consider multicellular organisms, the classical kingdoms of plants and animals.

Some 16 major categories are known among the multicellular plants, ranging from algae, fungi, and mosses, to ferns and seed plants. The most advanced division among these groups, the angiosperms, contains several hundred thousands of species.

The diversity, in the animal kingdom is, if anything, even greater. There are probably more than 3 million species of animals in existence, of which 1 million has already been described by systematists. The living animals are grouped in about 30 so-called phyla, each of which is set apart by structural characteristics that distinguish it clearly from all others. In order to bring home to you the enormous, the well-nigh inconceivable diversity of the animal kingdom, let me single out just 2 of the 30 phyla, the arthropods and the chordates. The phylum arthropods is subdivided into about 15 classes, the three best-known among which are the spiders and their relatives (including scorpions and mites), the crustaceans (including lobsters, shrimp, and countless small plankton types), and finally the insects with about three-quarters of a million of described species. In the phylum chordates I need only to mention the words mammals, birds, reptiles, amphibians, and fishes, all of them chordates, in order to remind you of the diversity in that phylum, and there are still some 28 other phyla of animals, not counting extinct types.

Let me now make my point! Can we explain this almost incomprehensible amount of organic diversity in biochemical terms? What role has chemical evolution played in the evolution of organic diversity? Were the many new evolutionary developments initiated by chemical mutations, or are the chemical changes observed in various phyletic lines merely a secondary response to selection pressures set up by evolutionary shifts in behavior or ecology and by the invasion of new adaptive zones?

To be honest, we must admit that we do not yet have the facts to give a complete answer. But we can advance some tentative formulations.

Let us look at two decisive steps in the phylogeny of organisms, the step from the procaryotes to the eucaryotes

and the step from unicellular eucaryotes to multicellular plants and animals.

The procaryotes, which includes the bacteria and the blue-green algae, differ from the higher protists, the eucaryotes, by greater simplicity, e.g., by a lower level of organization. They lack mitochondria and chloroplasts, that is, specialized organs for respiration and photosynthesis, and the nucleus is not separated from the cytoplasm by a membrane. In contrast, the most striking characteristic of the eucaryotic cell, as clearly stated by Stanier and van Niel (8), is that its major work areas of cellular function, i.e., respiration, photosynthesis, and genetic information transfer, are surrounded by individual membranes, creating thus a new level of intracellular organization. This organizational difference between procaryotes and eucaryotes is greater than any chemical difference between the two groups, except for the relative amount of DNA which is far greater in the nucleated protists than in the bacteria. And this is part of our story.

Let us now look at the second major phylogenetic step, that from unicellular to multicellular eucaryotes. Let me first say, that this step was probably taken repeatedly by independent lines, not merely by animals and plants, but perhaps several times among plants and possibly two or three times among animals. In no case is there a striking chemical difference, so far as I know, between the unicellular ancestor and the multicellular descendant. Rather, what the multicellular organization does is to provide the organism with an enormous new potential for a division of function and a specialization of parts and components. And in this the evolutionist can discern rather clear-cut trends.

Before discussing these, let me say a few words about evolutionary mechanisms, because this is an area in which there are still many misconceptions.

The evolutionary role of mutation was badly misunderstood by the geneticists early in the century. They regarded it a driving force and one that moved forward in distinct, clear-cut steps, indeed in the form of veritable saltations. This idea may have some validity for haploid, uniparentally reproducing microorganisms. Among higher, sexually reproducing organisms, however, the role of mutation is simply to replenish the genetic diversity of the gene pool. It is natural selection which, at any given moment, gives direction to the evolutionary trend. Yet even in haploid microorganisms with minimal genetic recombination, it seems that natural selection is far more important for evolution than mutation.

Natural selection is another often misunderstood concept. Is it the "traditional law of tooth and claw," as one biochemist has recently phrased it? Actually, nothing could give a more misleading conception of the working of natural selection than Tennyson's metaphor. Natural selection is a statistical process, referring to reproductive success as expressed in the relative frequency of descendants in the next generation, it is not a bloody struggle.

"Natural selection works on genes." This statement is

again totally misleading. Natural selection describes the reproductive success of individuals, that is, of phenotypes. To be sure, genes contribute to the selective valence of phenotypes and are therefore indirectly affected by natural selection. However, the selective superiority of higher organisms is mostly due to such components of the phenotype as tolerance to heat and cold, an ability to secure adequate food, to recognize and escape enemies, to reproduce, and to reproduce abundantly. Virtually all these characteristics are due to highly complex interactions of many genes. They are the products of whole gene systems. Evolutionary advances in multicellular organisms, therefore, are far more often due to the improvement of genetic and biochemical systems rather than due to singular biochemical inventions.

When we apply current concepts of the role of mutations and of natural selection, and of the relation between gene and phenotype to the process of evolution, we come to the conclusion that evolution among higher organisms must be an exceedingly gradual process. This conclusion is, indeed, entirely confirmed by the studies of biochemists, geneticists, paleontologists, and general evolutionists. Let me single out two important evolutionary processes to test this conclusion, the origin of new species, and the origin of new structures or organs, both processes interpreted by the early Mendelians on a macromutational basis. Actually, the origin of new species, except for the cases of polyploidy, is an exceedingly gradual process (2). It consists in the slow genetic reorganization of geographically isolated populations. (I do not have the time to discuss here the genuine difficulties posed by haploid and uniparentally reproducing organisms.)

The acquisition of new structures or entirely new organs is likewise a gradual process. Let us take, for instance, the lungs of terrestrial vertebrates. It is now fairly clear that they evolved approximately as follows: certain fresh-water fishes that lived in stagnating waters with insufficient oxygen adopted the habit of swallowing air and absorbing oxygen through the walls of the esophagus. Any enlargement of the surface area of the esophagus was of selective advantage under these conditions and diverticulae of the esophagus soon appeared which under continued selection pressure enlarged to bag-like lungs. The whole subsequent evolution of the lungs has been merely an elaboration of this original trend of enlarging the surface suitable for oxygen uptake and vascularizing it in such a way as to achieve maximal efficiency in oxygen transfer.

Let me emphasize once more the essential point of this story. There was no threshold where a sudden jump was made. The new system evolved very gradually, requiring undoubtedly many biochemical adjustments but not requiring any sudden biochemical revolutions. The only possible exception, the only possible quantum step in the whole long chain reaction, is the very first step, the development of the habit of swallowing air at the surface, and this could have been acquired, like many other habits, without any genetic change whatsoever.

Virtually all major evolutionary novelties, like the wings of birds and bats, the extremities of the terrestrial vertebrates, or the brain of man, are the products of a similarly gradual process.

There are usually several possible answers to a need of the phenotype. For instance, when multicellular animals increased in size during evolution, they evolved a skeleton, but it so happens that this was an internal skeleton in some phyletic lines, as in the vertebrates, but an external skeleton in others, as in the arthropods. This engineering aspect of the skeleton at once determined the limits of further evolution in these lines. An internal skeleton permits continuous and virtually unlimited growth, hence, the development of elephants, whales, and gigantic dinosaurs among the vertebrates. Growth in arthropods with an external skeleton is possible only through molts and the soft-shelled creature emerging after a molt is not only vulnerable to attacks by enemies, but also unable to support its weight properly. Horseshoe crabs, lobsters, and some long-legged crabs are the ultimate in size that can be achieved by an organism with an external skeleton. The dramatic difference between these phyla is probably due to the fortuitous accident that in comparatively small ancestral forms, in one case an internal and in the other case an external skeleton was invented. A further limit on the size of terrestrial arthropods is set by the inefficiency of their respiratory organ, the tracheae.

Evolutionists have often commented on the haphazardness and opportunism of evolution. But one should not exaggerate this aspect of evolution. Huxley (1) and Rensch (6, 7), have shown how many regularities can be found in evolutionary lines and have demonstrated, furthermore, that the resulting trends are caused by natural selection rather than by any teleological, finalistic principles.

In most, if not all evolutionary lines of multicellular organisms, there is a tendency toward a change in size, usually an increase, but under special circumstances toward a decrease in size. Among the advantages of size increase are that it permits *a*) a greater specialization of body parts, *b*) an emancipation from the environment, and *c*) a protection against enemies (see also (4)). Increased size, however, generates very specific demands. For instance, since all metabolic processes are more or less associated with membrane surfaces, that is, with two-dimensional structures while body size increases by the cube, the growth of all surfaces has to be exponential in comparison to the increase in body size.

The interior of the body is farther and farther removed from the surface with increased size, and simple osmosis is no longer sufficient to transport oxygen and nutrients to all the cells and to remove the waste products of metabolism. A premium is set up for the evolution of transport systems, that is, organs of circulation, respiration, digestion, and excretion, which bring cells in every part of the body in close and efficient contact with the outside world.

Increased size, however, places still other demands on

the organism of which I shall mention only two: *a*) a firm skin, epidermis, shell, or bark, which protects the organism against the loss of moisture and against attacks by microorganisms or small predators; and *b*) a skeleton to provide stability and prevent the collapse of the organism, particularly in the case of terrestrial organisms.

Similar generalizations can be made concerning trends in metabolism, control mechanisms, reproductive biology, sensory organs, the central nervous system, behavior patterns, and so forth. All these trends and specializations are made possible by the extraordinary flexibility which a multicellular organization gives to organisms. No case is known to me in which a change in body chemistry initiated a new evolutionary trend. Invariably it was a change in habits or habitat which created a selection pressure in favor of chemical adjustments.

In principle, the evolution of new kinds of higher organisms demonstrates the same phenomenon as the shift from procaryotic to eucaryotic protists. It is the development of new biological systems consisting largely of new constellations and differing proportions of the same basic unit elements. In other words, biological evolution is dominated by the continuous emergence of new systems: and systems often display characteristics which one could not have predicted on the basis of the properties of the unit elements.

I pointed this out, some years ago, in a lecture in Copenhagen which was attended by Niels Bohr. In the ensuing discussion, he agreed with my conclusions, except for reminding me that an emergence of new characteristics in systems was not peculiar to living systems. He cited the chemical elements, which are systems that owe their highly specific properties to the quantity and pattern of their simple unit components, the nuclei and electrons. These properties, Bohr said, could not have been predicted in detail on the basis of a knowledge of isolated protons, neutrons, and electrons. On the other hand, a study of the properties of these systems has taught us a great deal about the properties of protons and electrons.

The same is true for biological systems. Much of the difference among organisms is a matter of difference in systems rather than in unit components. A giraffe, an elephant, and a rabbit differ much more from each other in the relative size of extremities and organs and in other quantitative characteristics such as density of fur, thickness of the epidermis, relative frequency of various glands, and so forth, than in the presence or absence of certain basic chemical constituents.

The systems approach, which I have espoused in this discussion, is in strong contrast to an approach usually referred to as reductionism. It is the belief that systems can be fully understood by dissecting them, by analyzing them down to the lowest basic element. As valuable as an analytical approach is, in my opinion it is only a first step and should never be considered the final goal.

This still leaves us with a number of basic questions. Why is the organic world characterized by such uni-

formity in its basic chemical constituents and metabolic processes? Because there is usually only one kind of molecule or macromolecule which is able to perform a specific task with optimal efficiency. Considering the high selective premium on the acquisition of optimal processes, all basic inventions were already made at the bacterial level or earlier. Since macromolecules are endowed with unique properties, there is often only a single way to construct more complex macromolecules, and as a consequence, specialized macromolecules may independently originate repeatedly in different phyletic lines, formed by the same universally available constituents. The polyphyletic origin of hemoglobin is one example. The arthropods, mollusks, and vertebrates made, likewise independently, the invention to utilize carotenoids as visual pigments. The reason, of course, is that the "carotenoids alone among natural pigments have straight-chain conjugated systems, capable of readily undergoing *cis-trans* isomerization by light" (9).

The simple theory of a conspicuous parallelism between organic evolution and biochemical evolution is thus not supported. Nevertheless higher organisms differ chemically from their ancestors in manifold ways, as will be shown by the following speakers. Our revised question then must be phrased as follows: "What is the nature of the chemical changes that accompany the elaboration of ever more complex biological systems?" The answer to this question is beginning to emerge from modern genetics and from developments in biochemistry, which combine the best features of an analytical and a systems approach. In biochemistry we have acquired a whole new dimension of understanding through the systematic comparative phylogenetic study of characteristic macromolecules, such as hemoglobin or certain enzymes. The major part of this morning's symposium will be devoted to some of the exciting findings of these researches.

Let us look, in a very general way, at some of the results. A large enzyme may have some 300-500 or more amino acid residues, yet the so-called active site may involve only 10 or fewer residues. What then, may we ask, is the function of all those other residues which make up 98% of the molecule? These are the residues that used to be ignored and were discarded in the study of the active site!

Ever since I became a zoologist, I have been impressed with the functional significance of structure. It is perhaps for this reason that I am particularly intrigued by the frequently made suggestion that the tertiary folding of the polypeptide chains at the nonactive sites contributes significantly to the specific biochemical milieu of a species. As an evolutionist I am furthermore impressed by the power of natural selection, and I doubt for this reason that any particular amino acid configuration was ever replaced by a different one, unless this replacement was favored by natural selection. The reconstruction of an enzyme outside its active site has almost surely something to do with the control of enzyme

activity and precision in this control would be of high selective value.

An organism is not just a bag full of enzymes. As I have stressed throughout, everything in an organism is part of a system, and I agree with those biochemists who believe that much in the structure of an enzyme has significance for the interaction of the protein with other proteins. If, in the course of evolution, some of the proteins of an organism undergo evolutionary changes, it is easy to understand that this might create a selection pressure in favor of remodeling other proteins in order to improve interaction. A single amino acid replacement in a polypeptide chain may require additional substitutions in order to improve conditions for tertiary and quaternary folding. As an evolutionist, I am firmly convinced that natural selection exerts a continuous pressure on the interaction of the various chemical constituents of an organism. An improvement in one protein is apt to lead to unbalances in its interaction with other proteins and thus favor their reconstruction.

Our ignorance about the physiology of such changes and their selective significance is still almost complete. Yet, such work as that on the phylogeny of the hemoglobins, which clarifies the evolutionary changes in the alpha, beta, delta, and gamma chains, are preparing the ground for a better understanding. It has been shown by population geneticists that balanced heterozygosity, that is, the simultaneous presence of two slightly different homologous enzymes, sometimes leads to greater physiological flexibility in an organism and thus to greater tolerance for changing environmental conditions. It would reduce the genetic load of the population if the same versatility were achieved by the simultaneous possession of both enzymes even in homozygotes, owing to duplication, translocation, or other genetic mechanisms. The hemoglobins characterized by the simultaneous presence of both alpha and gamma chains may illustrate this principle.

Regulation and feedbacks are the most important aspects of systems which function through the interaction of components. Our ignorance is still nearly complete in this area. As far as the genetic information is concerned by which DNA governs the construction of complex systems, it is now believed that in addition to the structural genes, which control enzymes, there are operator and regulator genes, which in turn control the activities of the structural genes. Their existence introduces a whole new dimension of flexibility and diversity into the developmental pathways (3, 5). This is surely part of the reason why the amount of DNA in higher organisms is so much greater than seems necessary for the programming of their basic enzyme systems. All aspects of relative growth are presumably governed by such regulator genes.

Many, if not most, of the differences among closely related higher organisms consist of differences in body proportions or in the degree by which certain characters are expressed. Again, these quantitative differences are

presumably affected, if not wholly controlled, by regulator genes. Until now, we know virtually nothing about their functional pathways. I would not be surprised, however, if research on the action of operator and regulator genes would not some day converge upon the study of amino acid substitutions in enzymes at sites other than the so-called active sites. I rather suspect that these other sites have a good deal to do with the regulation of enzyme activity.

Let me summarize my conclusions. The evolution of organic diversity is to a large extent due to the elaboration of ever more complex, ever more diverse, systems. During much of this evolution the same basic chemical constituents or classes of chemical constituents have been utilized. However, there has been a great deal of modification of macromolecules, which presumably is correlated with the interaction of various proteins, and with regulation of enzyme activity. Evolution of higher organisms must be studied both as an elaboration of systems and through the analysis of the elementary units. A one-sided emphasis of one to the exclusion of the other will fail to produce true understanding.

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In biology, as already acknowledged in physics, the ideal approach is the combination of an analytical and a systems approach. The two approaches complement each other beautifully. The biologist studies systems of increasing complexity from molecules, macromolecules, cellular components, cells, tissues, organs, organ systems, individuals, families, populations, species, up to species aggregates. A system at any level is composed of elementary units which are the systems of the next lower level. On each level it is equally legitimate to study either the system as a whole or the elementary units of the system, but we will not get the whole truth unless we study both. It is fortunate, both for physics and biology, that systems at higher levels can be studied with profit long before the elementary units at the lower levels are fully understood. The past history of biology has shown that progress is equally inhibited by an anti-analytical holism or by a purely atomistic reductionism. A healthy future for biology can be guaranteed only by a joint analytical and systems approach.

From Molecules To Organic Diversity

E. Mayr

(Résumé)

En dépit de l'extraordinaire uniformité de leurs composants cellulaires et chimiques, il existe une diversité effarante des organismes multicellulaires vivants, animaux ou plantes.

Cette multiplicité des formes organiques est le fait d'une évolution. Cette évolution ne semble pas être la conséquence d'une mutation chimique au niveau des structures organiques.

L'évolution des organismes supérieurs est d'ailleurs un processus excessivement lent. Tout système nouveau s'est organisé progressivement, donnant lieu à certains ajustements biochimiques et non à des révolutions brutales des structures et ceci grâce à l'extrême flexibilité qu'une organisation multicellulaire donne aux organismes.

Ce sont les modifications du milieu ambiant qui créent une sélection en faveur d'une adaptation chimique déterminée (la mutation chimique est une redistribution des constituants).

L'évolution organique est donc en grande partie le fait de l'élaboration de systèmes toujours plus complexes, au cours de laquelle les constituants chimiques de base demeurent inchangés, tandis que s'effectue leur interaction au niveau des macromolécules. Il apparaît donc nécessaire que l'étude des organismes se fasse à la fois par l'analyse des unités élémentaires et par celle des systèmes en cours d'élaboration.

De las moléculas a la diversidad orgánica

E. Mayr

(Resumen)

A pesar de la uniformidad extraordinaria de sus componentes celulares y químicos, existe una asombrosa diversidad de organismos vivos multicelulares, tanto animales como vegetales.

Esta multiplicidad de formas orgánicas se debe a una evolución. Tal evolución no parece ser la consecuencia de una mutación química en el nivel de las estructuras orgánicas.

Por otra parte, la evolución de los organismos superiores es un proceso sumamente lento. Todo sistema nuevo se organiza progresivamente mediante ciertos ajustes bioquímicos y no mediante revoluciones brutales de estructura, lo que se debe a la gran flexibilidad que la organiza-

ción multicelular confiere a los organismos.

Las modificaciones del medio ambiente operan una selección en favor de una determinada adaptación química (la mutación química es una redistribución de los componentes).

Por lo tanto, la evolución orgánica es en gran parte el resultado de la formación de sistemas cada vez más complejos, en el curso de la cual los componentes químicos fundamentales permanecen invariables mientras que se efectúa su interacción en el nivel de las macromoléculas. En consecuencia, parece necesario que el estudio de los organismos consista simultáneamente en el análisis de las unidades elementales y en el de los sistemas en curso de formación.

THE TEACHING OF BIOCHEMISTRY IN SCHOOLS

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Recently there has been an increased interest in Biology teaching in Great Britain. Factors that have contributed towards this are the B.S.C.S. schemes from the U.S.A., the Nuffield Biology Course for England and Wales and, lately, the New Scottish Biology Scheme. These are new courses designed for use in schools for pupils up to "O" level. Probably one of the causative events was the work done to elucidate the role of D.N.A. To many School Biologists this seemed to be the key for the transition from the empirical approach of the older courses into the newer, integrated approach, for to regard D.N.A. as the basis of all life leads to courses based on the living organism instead of animal and plant types as separate organisms. Undoubtedly the use of the D.N.A. concept has led to familiarity with the use of complex organic molecules and terms such as hydrogen bonding. The problem that many teachers are facing is at two levels; how much chemistry is necessary for the new schemes of work and what must be done to allow a clear understanding of some of the concepts of Molecular Biology?

The difficulty in the use of Chemistry in the schemes of work up to "O" level lies largely in the need for teachers to change the emphasis from the descriptive approach which, in many cases, scarcely needs the use of a biology laboratory, to the experimental approach. This demands of the pupil the development of the use of the experimental technique and manipulation which has been used in Chemistry for many years. Certain chemicals are used in the courses, for example, the use of potassium pyrogallate for oxygen absorption or the use of hormones in the study of development. In such courses it is desirable for pupils to be studying Chemistry at the same time, both for the additional experimentation involved and for the increased understanding of the biological processes, however it is not a prerequisite of a new Biology course. It is possible to treat any Chemistry that is necessary in a purely empirical manner, in which the pupil is told that any chemical used is a tool in the biological process or measurement, for example, potassium hydroxide solution will absorb carbon dioxide so that this may be used in gas analysis. No further information or explanation is needed.

In the more advanced studies in Biology at school, post "O" level, the use of Biochemistry becomes more obvious and more demanding of the pupil. At the simplest level one uses the terms glucose, sucrose, starch, etc., in order to specify the general term "carbohydrates". To give a clear idea of their relationship one must refer to structure in order to indicate the processes of condensation and hydrolysis. Similarly an

understanding of the properties of amino acids and proteins can only come from a knowledge of their chemistry. This demands a clear understanding of chemical bonding and of organic chemical structure which is beyond that studied in "O" level work in Chemistry. To try to teach the Biochemistry of some of the advanced level work which can be introduced in the topic of Molecular Biology could need an even greater understanding of Chemistry than indicated above. In the structure of R.N.A. and D.N.A. one finds the following difficulties for the pupil ; ribose is not even a hexose sugar, but is of the unrelated pentose group ; the differences in structure between the various purine bases and why R.N.A. and D.N.A. should have different purine bases in their structure ; the explanation of the hydrogen bond and how it can hold these large molecular chains together. These are topics which should be left for the understanding which could only come with an appropriate Biochemistry course at the University. Most pupils in the school will accept that these compounds are different and will react as described by the teacher without further questioning, so that this type of Biochemistry is on the empirical system such as is taught for the "O" level pupils who do not have Chemistry. This type of teaching could rely on the use of the little shaped box to represent a particular compound, thus the fig. 1, in which the names of symbols are all that are necessary and without any further chemical information being given. The pupil then learns the names and the sequences and is told that there is obviously much more to this which may be elucidated at a later stage in the study of Biology. The main thing is that the pupil recognises the importance of the reactions, and has some understanding of how it works.

The further problem at this level is the chemistry of respiration and photosynthesis. There is the tendency in many schools studying for "A" level to enter into the details of glycolysis and the citric acid cycle. Pupils are set the task of learning the chemical processes which they are then able to reproduce in examination conditions. Few pupils understand the chemical relationship between successive compounds in this cycle ; generally they have insufficient chemical background. In this case it would be enough for the pupil to realise that respiration is not the simple process



but that the breakdown of glucose occurs in various steps, each giving out a small unit of energy. Pupils accept the concept of the energy rich phosphate bond in A.T.P. without excessive questioning of why it is energy rich. It is, of course, important to emphasise that chemical energy is the only means of energy transfer within the living organism, and that A.T.P. is the currency for this. Similarly with photosynthesis the uniqueness of the reaction must be stressed, but little of the biochemical mechanism need be given beyond the fact that there is a light reaction for gaining the energy and a dark reaction for utilising it. Where the pupil is well prepared they may be able to understand the biochemical process, but where this is not so, a brief outline may be given at the school level hoping that this may help a full understanding at the degree level of Biology. Any attempt for a full study of Biochemistry at School must be made extremely difficult for the lack of practical work and suitable apparatus to back up the work done in theory.

It is apparent that with the new schemes of work in Biology, a study of Chemistry should be undertaken parallel to that in Biology at all stages, both for the experimental manipulation and for the background necessary for a full understanding of the biochemical aspects of the work. However it is not impossible for the pupil without Chemistry to embark on these courses providing that the Biochemistry is kept to a simple learning of names in order to understand a biological principle, e.g. names of enzymes or hormones. It would be difficult for the teacher of Biology to undertake all the Chemistry teaching necessary.

The other alternative is to avoid Biochemistry in the schools and to delegate this to the Universities. Here the facilities for such teaching are better than in most schools and they should be able to provide the background Chemistry necessary. Few Universities in England and Wales offer courses in Biology or a Biological Sciences without a previous qualification in "A" level Chemistry: in my last experience they numbered three. These Universities provided a course in Biological Chemistry to suit their particular course in Biology.

There is much to recommend the Scottish Higher Grade examination system which is taken at the age of 17+ and has relatively little specialisation. This allows the Universities to undertake the more specialised work, which is attempted in A-level courses in English schools. The Scottish system allows a pupil to defer a decision on the field of Biology he wishes to specialise in, and it would seem to be the best arrangement where the facilities for specialised A-level courses.

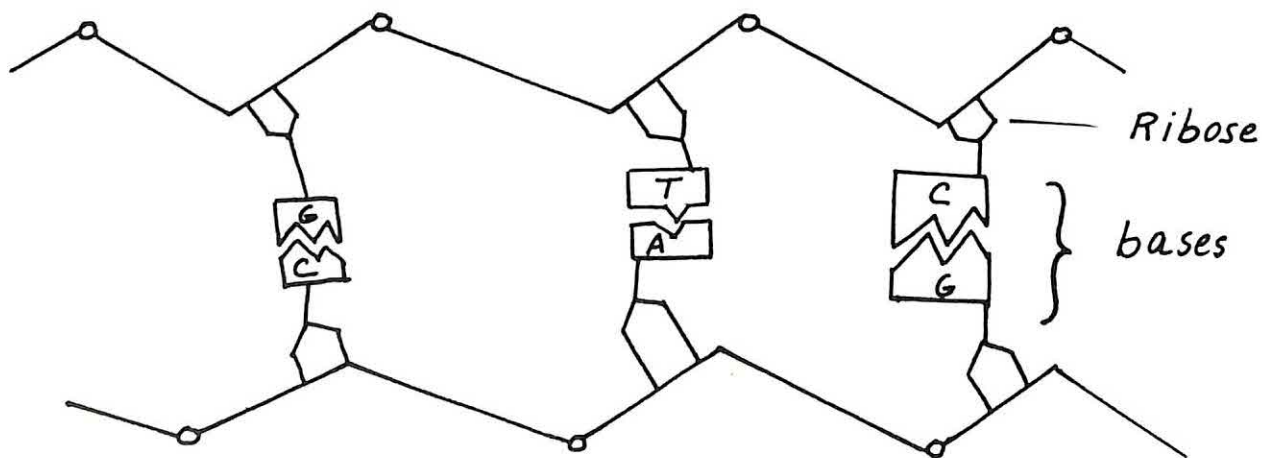


Figure 1

The teaching of Biochemistry in Schools

R.W. Heath

(Résumé)

L'enseignement de la Chimie, en rapport avec celui de la Biologie, est discuté à la fois pour les niveaux de travail "O" et "A" ; au niveau inférieur il est utile de prévoir des expériences pour aider la compréhension de la Biologie. Au-delà du niveau "O", pour parvenir à une bonne compréhension des molécules complexes et de leur structure, il faut des bases chimiques appropriées. Il est discutable de savoir si les notions de Chimie enseignée à l'école sont suffisantes pour avoir une claire compréhension de la Biochimie, mais le sujet peut être étudié de telle sorte que l'étudiant comprenne l'importance de processus tels que la respiration et la photosynthèse. On suggère que les Universités dispensent des cours de Chimie propres à permettre aux étudiants d'avoir des bases assez bonnes pour comprendre la Biochimie ou la Biologie moléculaire.

La enseñanza escolar de la bioquímica

R.W. Heath

(Resumen)

Se examina simultaneamente para los niveles de trabajo "O" y "A" la enseñanza de la química en relación con la de la biología. En el nivel inferior conviene utilizar experimentos para facilitar la comprensión de la biología. Por encima del nivel "O", para conseguir una buena comprensión de las moléculas complejas y de su estructura, hacen falta bases químicas apropiadas. Cabe discutir si las nociones de química enseñadas en la escuela son suficiente para lograr una clara comprensión de la bioquímica, pero el tema puede estudiarse de manera que el estudiante comprenda la importancia de procesos tales como la respiración y la fotosíntesis. Se propone que las universidades dispensen cursos de química que permitan a los estudiantes adquirir las bases suficientes para comprender la bioquímica o la biología molecular.

THE USE OF RADIOISOTOPES IN BIOLOGY

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The present trend in biology is toward the use of physical and chemical methods of investigating the basic life processes. Research workers are concentrating primarily on problems of the physical and chemical basis of vital phenomena such as metabolism, growth, reproduction, heredity, and mutation at the submicroscopic or molecular levels. One of the very important and widely used methods currently used to investigate a wide variety of problems is the use of radioactive chemicals, whose ready availability has been brought about by the developments and achievements of nuclear physics and the growth of the atomic industry. At present, nearly all the chemical elements that make up the living system are available in radioactive forms and have become important in the study of life processes. The applications of these radioactive chemicals to biological research has become so enormously diversified that little more can be done here than to list the types of work undertaken and to describe a few typical examples. But first, let us first understand what radioisotopes are and the techniques employed in their use. Then we will examine examples of their widespread use in biological research.

A change in the physical composition of the atom is necessary for the production of a radioactive element. An atom is divisible into three distinct particles ; neutrons, protons and electrons. The positively charged protons and electrically neutral neutrons, which are responsible for the majority of the atomic mass, comprise the central nucleus around which orbit negatively-charged electrons. The atom is electrically neutral since the number of electrons and protons is the same. The number of protons is referred to as the Atomic Number and the atoms of any element always have the same atomic number, i.e., the number of protons always remain the same. However, these atoms need not have the same number of neutrons per atoms ; in fact, the number of neutrons per atom can vary within certain limits. Atoms having the same number of protons but different numbers of neutrons are termed isotopes. Isotopes are of two major types : the number of neutrons associated with a given number of protons may vary within certain physical limitations, some of which are stable and are referred to as stable isotopes. The remainder, or non-stable configurations, undergo spontaneous nuclear reorganization to form a more stable combination of protons and neutrons. In the process of reorganization, excess mass or energy is emitted and is called nuclear disintegration ; these latter types are termed radioactive isotopes and the rate of disintegration (commonly referred to as "decay") is such that in any period of time a given portion disintegrate. One customarily uses the term "exponential" to describe this

type of decay rate. The time it takes for one half of the isotopic material to decay is termed the "half life", which can vary from a few millionths of a second to days, months, or years depending on the isotope. The probability that any atom of an isotope will decay is characteristic for that isotope. Table I lists some of the isotopes commonly used in biological research and also gives their "half life" and type of radiation emitted. Scientists have agreed upon a nomenclature and it is now customary to use the alphabetical abbreviations for the elements with the atomic weights at the upper left corner. The atomic weight is a relative term referring to the weighted mass of carbon. For example ^{12}C , refers to "normal" non-radioactive carbon and ^{14}C would be a carbon atom with two additional neutrons in its nucleus. This latter type of carbon is radioactive and is referred to as a "carbon-14". Normal non-radioactive sodium which has almost twice the weight mass per atom (^{23}Na) as compared to "normal" carbon (^{12}C) can accommodate one additional neutron and thus becomes ^{24}Na which is a radioisotope and will eventually disintegrate. It should be understood that "carbon-14" or "sodium-24" are not radioactive in the state of possessing extra neutrons. It is only when these atoms undergo a change of state that they are then radioactive. In other words, it is the actual process of disintegration that releases the radioactivity and until that particular atom disintegrates it is not radioactive.

The nuclei of radioisotopes may emit alpha (α), beta (β), and gamma (γ) rays. Alpha-particles are fast-moving helium nuclei, each containing two protons and two neutrons. Beta particles can be positively or negatively charged high-speed electrons, and gamma-rays are electromagnetic wave packets (photons) of very short wave-length compared with visible light but travelling at the speed of light. The relative abilities of these various types of radiation to penetrate matter is illustrated in Figure 1.

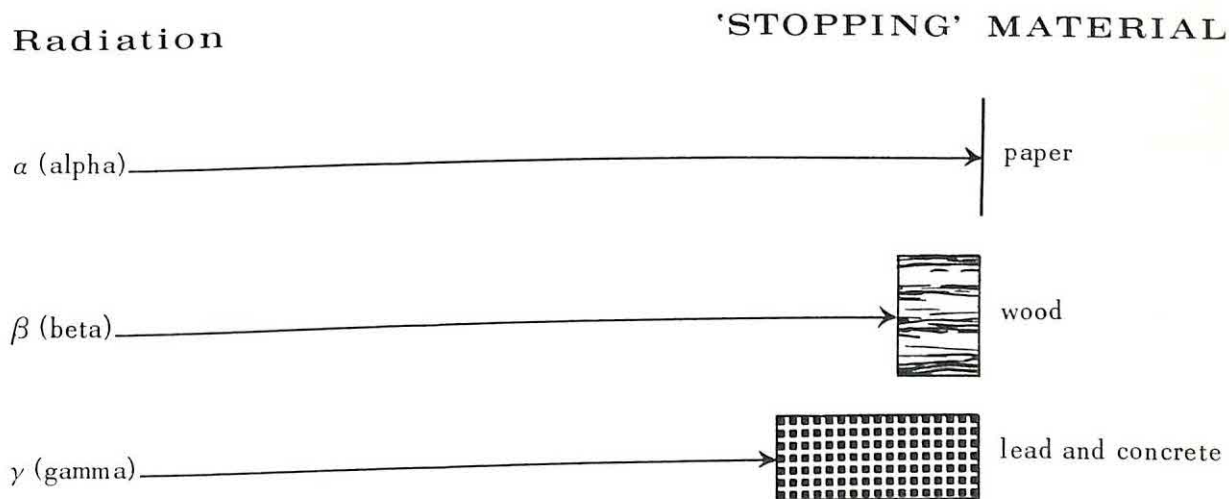


Fig.1.- An illustration of the relative penetration abilities of alpha, beta, and gamma rays.

These various types of radiations interact with matter in the form of ionizations and excitations which can be detected by a wide variety of detector instruments. The efficiency of these various instruments is illustrated by the fact that radio-isotopic analysis can detect the presence of a chemical at one-thousandth the dilution normally used for chemical analysis. In practice, all these detector measuring instrument utilize an electric field : the radiation interacts with the electrical charge present in the detector and produces a measurable alteration of the electric potential. This alteration is usually indicated by a gauge which yields a count rate (R) of the sample (S) for a certain period of time (T). Thus,

$$R = S/T$$

It must be remembered, however, that there is always present a certain amount of "background" irradiation (r) and thus it is necessary, after counting the sample, to determine similarly the count rate of a blank specimen(s). Background irradiation can be present in the form of natural cosmic rays or as radioactive contamination of the sample. In order to arrive at the true count rate of a sample, one must also measure the background count according to the formula

$$r = s/t$$

Then, by subtracting, the net count rate of the sample (A) is known

$$R - r = A$$

The counts per minute of the sample is an indication of the amount of radioactive element per unit weight of the element present. The relationship between the isotopic atoms and the total atoms of the element per weight in the sample is expressed as "specific activity". The amounts of radioisotope are usually expressed in microcuris (Ci), where one Curie (Ci) corresponds to an amount of radioactivity undergoing 3.7×10^4 disintegrations per second. One disintegration is the changing of the atom from one state to the next. In other words, one disintegration is the changing of sodium-24 to sodium-23 or of sulfur-35 to sulfur-34. Furthermore, if a certain element, says sulfur-35, is labelled as 0.52 mc/g it means that for each gram of this material there are $0.52 \text{ mc/g} \times 3.7 \times 10^4 \text{ disint/mc/sec}$ or 1.92×10^1 or 19.2 disintegration/g/sec.

In most biological research employing radioisotopes, there are two explicit assumptions : 1) the radioisotope and the molecule containing it behave exactly as its stable non-radioactive counterpart, and 2) the tracer radiation does not disturb the biological system. Both of these assumptions should always be tested since radioisotopes with high specific activities are known to affect the biological material e.g. heavy doses of tritiated-thymidine (^3H -thymidine) have been shown to produce chromosome abnormalities and increase the duration of the cell cycle. Similar amounts of non-radioactive thymidine do not appear to affect the cell and thus the logical conclusion is that the irradiation itself is causing the disturbances. Therefore, small amounts of radioactive thymidine must be employed if one wants to study an undisturbed system. A third condition which must be met is that the radiation emitted can be measured : this latter condition is met by using enough tracer so that the system, when and if it in-

corporates the tracer, will contain an amount of radioactivity that is significantly above the normal background level. In other words, one must use an amount of tracer that is not too much and not too little: trial and error is probably the only method for arriving at a suitable and convenient amount for use in experiments.

The exact choice of a radioisotope for use in an experiment is generally based upon the physical and metabolic characteristics of the system. For example, some elements and their radioisotopes are used solely to mark or label organisms in order to study such things as dispersal patterns. For example, if you were interested in studying the dispersal pattern of tree-boring insects you might paint them with radioactive cobalt (^{60}Co) this radioisotope has a long half-life, and is easily detected since it is a strong gamma-ray emitter. If you painted your insects with a radioactive beta-ray emitter, for instance ^{14}C , you probably would not be able to detect the location of the insects once they had bored into a tree since the beta-rays are not strong enough to penetrate the bark. The radioactive forms of metabolically utilized biochemicals such as a proteins, antigens, or amino-acids are used for physiological experiments. There are other factors, too, which must be considered in selecting a suitable tracer for a given experiment: these include half-life, energy, and type of radiation emitted. As a further example if one is interested in studying over-wintering patterns of tree-boring insects then an isotope with a long half-life must be used since the experiment will last several months. As with the above-cited tree boring insect experiment one would also select for this experiment a radioisotope which emitted a high-energy ray such as a gamma-ray since the weaker emitted beta rays would probably not be detected due to the ability of the bark of the tree to filter out beta-rays but not gamma-rays.

The advantages of the tracer techniques are (1) its very great sensitivity since many elements are present in such small amount that they are difficult to measure chemically. Very much associated with this particular advantage is a basic principle of tracer use that the isotopic atoms mix uniformly with associated pools of non-radioactive atoms and therefore serve to reveal their presence by its emitted radiation. (2) the possibility of intermittent, continuous or repeated measurement of internal incorporation from the outside and thus not disturbing the organism or, in some cases, its environment. (3) The use of radioisotopes extends the sensitivity of ordinary procedures by facilitating the detection and estimation of separated compounds. For example, it was shown that a dietary intake of about 1 mg of cobalt per day satisfies the requirements of a cow for this element. The determination of the distribution and excretion of such a tiny amount of this element is practically impossible by ordinary chemical means but was routinely studied by radiotracer techniques when ^{60}Co was administered. The tracer technique does of course, have certain disadvantages: (1) extreme caution must be employed since there is always the necessity to avoid spilling the radioactive material and contaminating the laboratory; (2) special shielding material must be used in some cases; and (3) special procedures must be rigidly adhered to in disposing of the radioactive material and organisms. Aside from these general "health hazard" precautions, (4) the procedures often involve expensive and complicated detector instruments.

A variety of techniques are employed to study the qualitative and quantitative aspects of radioisotopic incorporation. Isotope dilution employs the principle that for a given amount of radioactivity the specific activity is inversely proportional to the total amount of test substance present. Suppose, for example, you wish to determine with a radioisotope the quantity of water in a glass. You must know only the specific activity of the radioisotope, which we will say is 200 counts/min/ml; one millilitre of the isotope is then mixed thoroughly with the glass of water and its count rate determined. For purposes of illustration we will say a count rate of 2 counts/min/ml is obtained. It is obvious that the original activity of the isotope has been diluted 100 times: in other words, the glass of water originally contained 100 ml of water. The amount of dilution in the incorporating object (the glass of water) is a function of the amount of test substance in the original material. In other words, the method consists of incorporating uniformly a small amount of the labelled test substance in the material to be analysed and then isolating some of the test substance from the mixture and determining its isotopic content.

The dilution of radioisotopic compound with its normal radioisotope obviously results in the reduction of specific activity. The reduction of activity can be used to calculate the amount of the original non-radioisotopic compound. To do this type of "dilution" experiment the amount (M^*) and radioactivity (S_z) of the original labelled test substance must be known and the amount of radioactivity of the diluted, radioactive isolate (S_e) later determined. The amount of indigenous substance in the mixture (M_1) can then be calculated according to the formula

$$M_1 = M^* \frac{(S_e - S_z)}{S_z}$$

For example, radioisotopes are playing an important role in the elucidation of the chemical composition of biological compounds. A hydrolyzed protein can be analysed for a particular amino-acid content, say, glycine. The procedure would be as follows: a definite amount of hydrolysate (152 mg) is mixed with a small amount of radioactive glycine (5 mg) whose specific activity is known accurately (96 count/minute/mg). The diluted radioglycine is then isolated and purified, and showing a specific activity of 51 c/m/mg. The original amount of inactive glycine in protein (M_1) is then calculated

$$M_1 = \frac{(5 \text{ mg}) (96 \text{ c/m/mg} - 51 \text{ c/m/mg})}{51 \text{ c/m/mg}} = 4.4 \text{ mg}$$

Since the amount (4.4 mg) was originally present in 152 mg of hydrolysate, the percentage of glycine in the hydrolysate can then be calculated.

$$\frac{4.4 \text{ mg . glycine}}{152 \text{ mg hydrolysate}} \times 100 \% = 2.9 \%$$

The Double Dilution Technique allows one to estimate what proportion of an element or compound in a given sample comes from one source and what proportion from another. The simultaneous use of two radioisotopes is made feasible since measurements of each in the same sample is possible. This technique of double labeling offers a means of comparing directly in a biological system the movement, synthesis or degradation of two substances. For example, suppose one wants to determine the percent of glutamic acid in a wheat gluten hydrolysate made radioactive by growth of the plant in an atmosphere containing $^{14}\text{CO}_2$. To an aliquot containing 5320 c/m is added 10 mg (M_1) of glutamic acid. The specific activity of the isolated glutamic acid is then determined and is found, say, to be 151 c/m/mg (S_1). To another aliquot of the radioactive hydrolysate containing an equal number of counts is then added 20.0 mg of glutamic acid (M_2) with a specific activity of 78.0 c/m/mg (S_2). The problem now is to solve for the percent of glutamic acid in the gluten. Two simultaneous equations are used :

$$M^* = \frac{S_2 M_2 - S_1 M_1}{S_1 - S_2}$$

$$S^* = S_1 + S_1 M_1 \frac{S_1 - S_2}{S_2 M_2 - S_1 M_1}$$

Solving the equations :

$$M^* = \frac{(78)(20) - (151)(10)}{151 - 78} = 0.7 \text{ mg}$$

$$S^* = 151 + (151)(10) \frac{151 - 78}{1560 - 1510} = 2360 \text{ c/m/mg}$$

The 0.7 mg of M^* is therefore equivalent to 70 percent of S^* or 1650 c/m. The percent of glutamic acid in the gluten is $1650/5320 \times 100\% = 31\%$. In this double dilution procedure, two purifications are required but one is able to make a determination of a radioactive substance contained within a system made radioactive by two different radioisotopes. These types of procedures have a very wide range of application, from the biochemist studying biosynthetic pathways to the molecular geneticist interested in relating biochemical markers to inheritance patterns.

One technique which has found application in establishing the precise location of labelled material within a tissue, or even within a single cell is autoradiography.

Autoradiography is based upon the principle that ionizing radiations act upon a photographic emulsion the same way as light does. Thus, a piece of unexposed photographic film when exposed to an object containing a radioisotope produces a photographic image which upon development reveals the location of the radioactivity in the sample. The photographic image is called an autoradiograph.

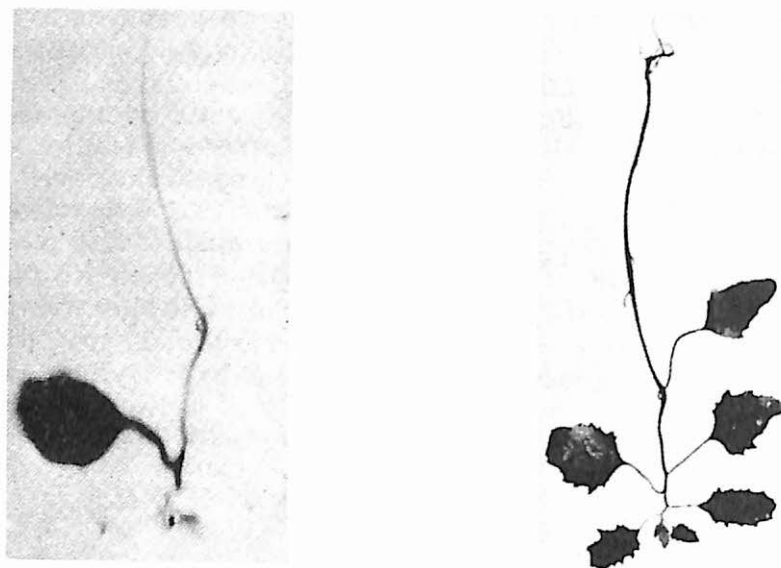


Fig.2.- A plant with one leaf treated by a radioactive isotope (left). The autoradiograph of the same plant showing that the radioactivity is located in the leaf and has not been transported to other leaves (right). (courtesy of IAEA).

For example, figure 2 shows a plant and its autoradiograph. One leaf of the plant was treated with a radioisotope and then later the plant was simply flattened with a piece of unexposed photographic film placed over it. The areas of high radioactivity in the plant have produced a photographic image on the film which indicated that the radioactive isotope remained in the leaf and was not transported to other parts of the plant. Autoradiography is particularly suitable for studying the time of arrival and distribution of a radioactive compound in the cell. In figures 3 and 4 a radioactive chemical was first applied to the cells. After a certain period of time the cells were spread on a microscope slide and coated with a photographic emulsion. The coated slides were then stored in the dark for a certain period of time and then processed according to a routine photographic developing procedure. The areas of high radioactivity are then observed and correlations with the radioactive chemical and cell structure can be made since the places of radioactivity will show dark spots (called "grains") which are superimposed over the cells. Figure 3 shows that the tritium label is incorporated into the nuclei of the human amnion cells and in figure 4 the tritium-labelled thymidine is shown to be located in the chromosomes of the Chinese Hamster cells. In fact, a careful examination of sections c - f of figure 4 will reveal that the label is distributed over single chromatids: this has been interpreted to indicate that the DNA (thymidine is a precursor of DNA synthesis) in chromosomes replicates in a semi-conservative pattern. There are, of course, many similar types of examples which could be cited as a typical example of the use of autoradiography in biological research. For example, specific cell types in popu-

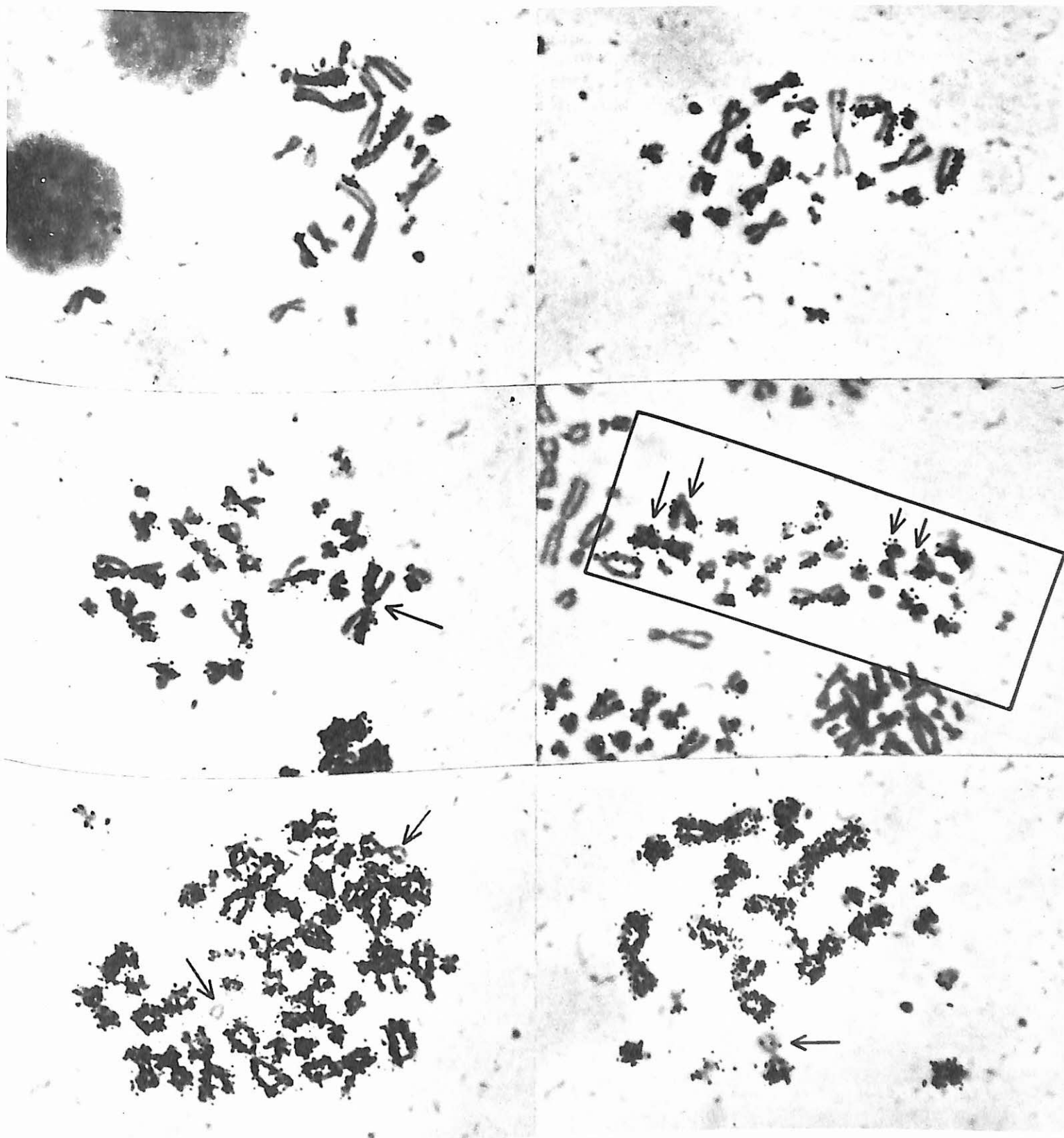


Fig. 3.- The autoradiographic localization of a radioactive tracer in human amnion nuclei (courtesy of Dr. J.E. Cleaver).

lations of cells have been identified with autoradiography, proliferative and mature cells have been identified, intracellular movement of fluids followed, and tissue deposition of radionuclides have been some areas in which this type of research has yielded valuable results. The general references listed in the bibliography contain illustrations of a wide variety of applications of autoradiography.

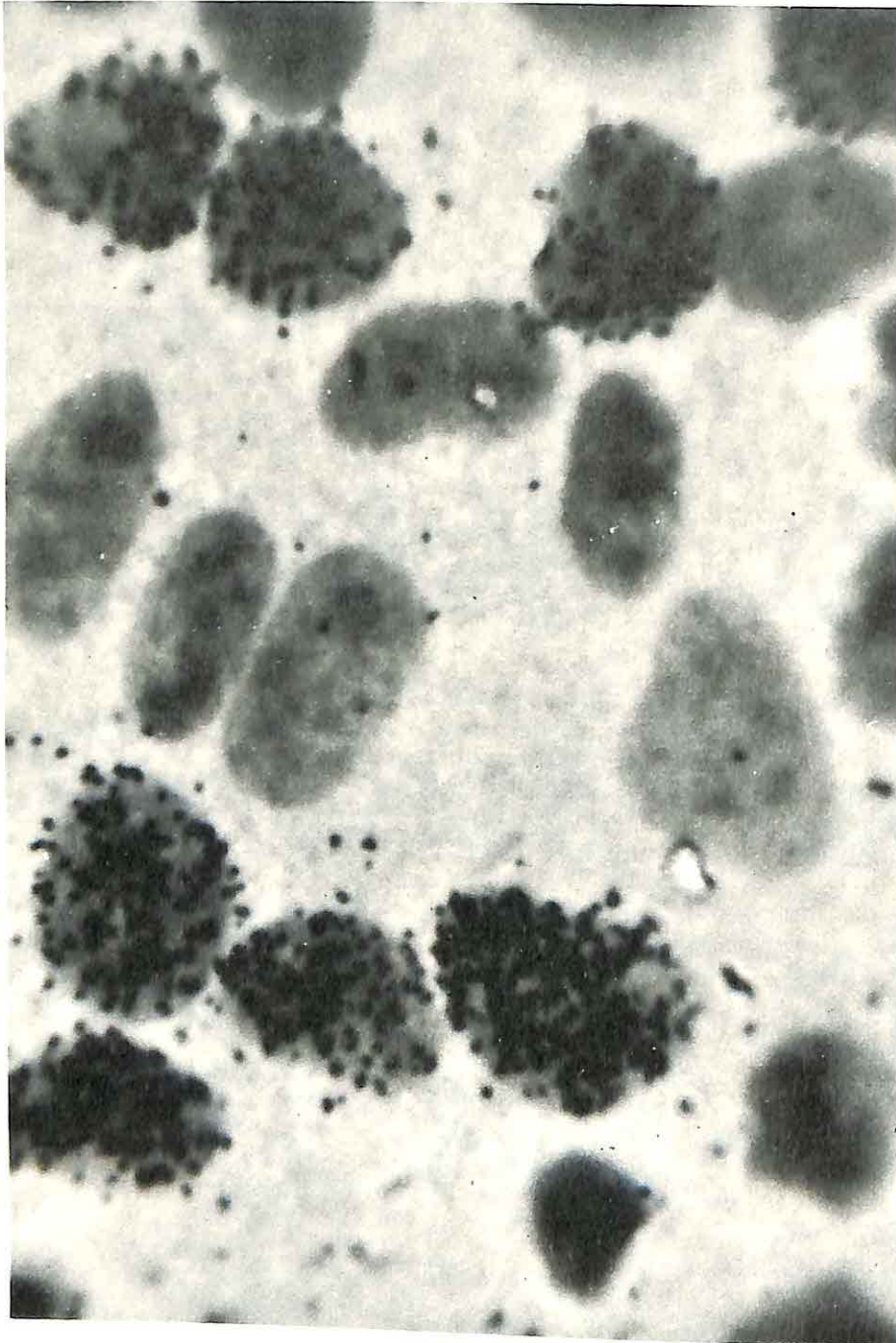


Fig. 4.- The autoradiographic localization of a radioactive tracer on human chromosomes (courtesy of Academic Press, Inc., N.Y.)

A very special use of radioisotopes is as a clock. This is the radioactive dating technique which has made invaluable contributions to the fields of geology, anthropology, archaeology, etc. Cosmic rays in the atmosphere are continuously forming ^{14}C from nitrogen. All material in the life cycle which involves exchangeable CO_2 are therefore uniformly labeled with $^{14}\text{CO}_2$, whose incorporation ceases with the death of the organism. Thus at the time of death the $^{14}\text{C}/^{12}\text{C}$ ratio begins to decrease in amount owing to the radioactive decay of the ^{14}C without replenishment, and by comparing the specific activity of the relic with a contemporary sample the time that has lapsed since the death of the relic can be calculated. The whole technique, then, is based on the lack or decreased amount of radioactivity. The half life of ^{14}C is 5568 ± 30 years and with present techniques determinations can be made in the range of 500-30,000 years.

One recently developed technique involves the formation of radioactive species at the end of the experiment. This process is known as radioactivation analysis and is based upon the principle that when a sample is exposed to a flux of bombarding nuclear particles produced by a high energy source of radiation such as a nuclear reactor, cyclotron, or linear accelerator, the elements contained therein become activated to radioactive forms. The reaction that takes place is one in which bombarding nuclei react with nuclei of the specimen. Bombarding particles which have been used to effect nuclear reactions are neutrons, protons, deuterons, tritium, ^4He , ^3He , photons, electrons and others but the neutron is the most extensively used because of its ready availability from a reactor. Radioactivation analysis is then a method of quantitative analysis of a certain element after conversion of that element into a radioactive form under irradiation of particle beams : it is a type of non-destructive analysis. In reactor activation, a relatively thin sample to be analyzed is placed in a uniformly high flux of neutrons for a length of time sufficient to produce a measurable amount of radioisotope of the test element. Each activated element has definite and unique half-life and radiation emission (spectrum) characteristics that can be measured and resolved, and thus can be identified. The measuring detectors for this procedure are extremely sensitive. For instance, when enough material is not available for ordinary flamephotometry, often as little as one-thousandth of the ash necessary will suffice for accurate radioactivation analysis. Thus, this method has three very distinct advantages :

- 1) very small samples can be accurately determined ;
- 2) the sample can be made radioactive after the experiment is finished ; and
- 3) there are no contamination problems since all elements have different radiation qualities.

A brief review of the uses of radioisotopes in all phases of the life sciences can perhaps give only a comprehensive indication of the radioisotopic applications in the general field of botany, zoology, biochemistry, and their inter-related disciplines. Nearly all aspects of metabolism has been studied with isotopes and presently the most important trend is in the study of biochemical pathways and mechanisms ; these investi-

gations include the biosynthesis of nucleotides and nucleic acids, the synthesis of lipids, the biosynthetic pathways of hormones, vitamins, and enzymes and photosynthesis. Studies have also been concerned with plant and animal metabolism (^{24}Na , ^{42}K , ^{48}Mg , ^{45}Ca , ^{90}Sr and ^{59}Fe), permeability, diffusion and absorption of substances, the physiology of blood circulation and other fluids, and immunology. Plant physiology, particularly the action of growth stimulators and selective herbicides, microbiology, hydrobiology, entomology, ichthyology, genetics and cytogenetics are all general areas in which radioisotopes have found a wide range of application.

One of the now "classic" examples of the use of radioisotopes in biology has been the elucidation by Calvin of the metabolic pathways of photosynthesis. Isotopic tracers allow the study of this living process under physiological conditions and thus enabled the distinction between molecules synthesized after the administration of radioactive CO_2 from those present prior to the onset of the experiment. In the particular case of photosynthesis the procedure was simply to expose the experimental algae to $^{14}\text{CO}_2$ for specific times under controlled conditions and to determine into what organic compounds the carbon-14 had been incorporated. The primary photosynthetic product was found to be phosphoglyceric acid (PGA) formed by the union of CO_2 and a 5-carbon acceptor molecule (ribose - diphosphate) that splits into two molecules of PGA. When the plants were supplied with $^{14}\text{CO}_2$ and illuminated, the label appeared in many carbon compounds including fats and proteins but when illumination was for only two seconds most of the label was found in PGA, indicating that this is the first biochemical step in photosynthesis. This is a typical example of how a radioactive label enters into the cellular metabolism of a living system and by chemical separation of the various metabolites can be used to elucidate fundamental biochemical processes. Similar types of experiments have been done in studying the production of sugars from corn and tobacco plants, drugs from medicinal plants, and the production of various amino and nucleic acids, vitamins, fats and some pigments. In animals, much the same techniques and principles have been employed: for example, by administering ^{55}Fe to animals it is possible to distinguish and study newly synthesized haemoglobin. In experiments of this type the labelled compound can be used to determine whether or not it is incorporated and thereby indicating whether or not it is an intermediate product involved in the synthesis of a specific biochemical. The tracer technique also has applications in studying the catabolism of biologically important molecules. Likewise, factors such as oxygen tension, pressure, mineral nutrition which influence the rate of incorporation of labelled compounds can be studied to further characterize the basic biological system. It must, of course, be understood that when using a radioisotope one should distinguish between the atom and the molecule. For example, ^{32}P labelled phosphate ($^{32}\text{PO}_4$) acts as a molecule whereas with salt (NaCl) labelled with ^{24}Na , the sodium in solution acts as an atom because of ionization.

Among the most important contributions of nuclear science to the welfare of mankind has been the utilization of radioisotopes as a valuable tool for research on technical factors involved in agricultural production. A better knowledge of the movement and availability of plant nutrients and

water in soil have lead to improved agricultural methods involving the timing, placement and composition of fertilizers. For example, with regard to the movement of soil nitrate during summer months, it had been observed that the nitrates accumulate at the uppermost soil surface. By using ^{15}N , a "heavy" or stable isotope, it was confirmed that the nitrates are not made at the soil surface but actually come from underlying layers. Thus it became quite clear that nitrogenous fertilizers should be placed at a depth of 15 cm or more wherever hot climates or dry periods occur, since otherwise the plants show signs of nitrogen-deficiency even in a nitrogen-rich soil. However, the opposite relationship has been found for phosphorus utilization. Using ^{32}P -labelled fertilizer one can show that when the fertilizer is localized on the soil surface there is greater assimilation than when the phosphorus is distributed evenly throughout the soil.

Radioisotopes have been used to demonstrate that the leaves, stems and fruits are all able to absorb nutrients. Radioactive boron (^{10}B) has been used in feeding roots and was shown to be readily absorbed but quickly immobilized: thus, in treating boron-deficient plants regular foliar spraying is recommended. Likewise, it has been demonstrated with radioisotopes that the above-ground plant parts may lose materials by the leaching or washing action of an aqueous solution. Strontium-90 has been applied to the leaves of potato plants, and while it is not easily moved into other plant structures it nevertheless has been shown to be removed by the leaching action of rain or mist. Such effects are of importance to plant nutrition as well as being related to soil formation and fertility, and an assessment of environmental parameters for plant strontium-90 uptake.

The effect of varying moisture levels in desert soils on phosphorus uptake by plants is concerned with the feasibility of converting desert territory to productive agricultural land. A raising of the desert soil moisture content from 11 % to 24 % caused an increase in the uptake of ^{32}P with growing corn plants, with a corresponding increase in the phosphorus content of the vegetable growth. No detectable changes occurred with barley until the soil moisture was raised to 28 %. These types of results indicate that desert soil must be maintained at a moisture content near its moisture-equivalent level in order to ensure suitable conditions for plant growth. However, because of the high cost involved in producing this level it may not be financially realizable.

The comparative absorption of herbicides by different plant species and the movement and distribution of herbicides within a plant have been investigated with isotopes. Weed research has been principally concerned with the residual effects in plants and soils and the detoxification of herbicides. The tracer technique has been used to identify degradation products and to trace the ultimate metabolic fate of herbicides. In young cereal plants the spraying of the herbicide 2,4-D produces deformities in the later-formed reproductive structures containing the grains. Experiments conducted with a labelled herbicide at all stages of development and examined with whole plant autoradiography showed that the herbicide is transported throughout the entire young plant, passing readily into the floral primordia but that labelled 2,4-D applied to slightly older 5-6 leaf stage plants was only slightly transported and did not extend to the growing point.

The mode of herbicidal action is of great importance and its study will be related to the development of better and more efficient herbicides. Labelled 2,4-D has been shown to move in the plant phloem with the food. Of particular interest is the fact that plants have different tolerances to herbicides ; autoradiographic and counting techniques were used to show that the Broad Bean's great sensitivity to herbicides may be explained by its large absorption : other plants, however, may absorb similar quantities but have some ability to metabolize the herbicide to non-toxic products. Similarly, the decomposition of radioactive herbicides in the soil, as studied by the rate of $^{14}\text{CO}_2$ production, has been shown to be dependent upon the type of soil. Such information is important in considering the amount of herbicide to be used in regions where the plant "black rust" disease is prevalent and spraying is done by airplanes.

All weed control, particularly chemical weed control, is applied plant physiology and biochemistry. Autoradiography has made it clear that herbicides actually move with the food materials in the plant and not along independent gradients. Thus, for certain types of plants it has been recommended to spray at certain times of the year when little top growth occurs and the food movement is largely downward into the roots, since then root resprouting would also be inhibited.

A very serious problem affecting the world's food supply is the enormous amount of direct and indirect damage done by insects to agriculture crops and livestock. Radioisotopes are playing a unique role in opening new avenues for research and approaches to newer improved control methods. Research with radioisotopes has added knowledge to the understanding of insect behaviour and physiology, and this knowledge has been employed in developing better control techniques and more efficient herbicides.

The most successful approach to controlling insects has been to gain first an understanding of their life histories. Radioisotopes are excellent tools for carrying out detailed and accurate ecological studies on insect pests ; contrary to usual methods, it is possible with radioisotopes to visualize exactly the dimensions of nests and the area over which their influence extends without disturbing the ecological and demographic distribution. The dispersal and distribution of labelled insects, their movement and behaviour underground or within trees can be studied due to the extreme sensitivity of the detecting instruments. Studies have been undertaken with labelled flies, ticks, mosquitos, and other insects which transmit diseases : host-parasite relations have been investigated to elucidate life histories and to locate the radioactive parasite within the host animal at different time intervals and also to determine egg laying and overwintering sites.

The most commonly used radioisotopes for ecological studies are beta-emitters such as ^{32}P and ^{89}Sr : these have suitable half-lives, effective incorporation and retention in the insect, low toxicity, ease of detection and handling, and low cost. However, for locating insects underground, in and under debris and bark, a strong gamma emitter such as ^{60}Co or ^{141}I is frequently used. The usual method of labelling is to mix the isotope with the food or drinking water, to inject, or to label exter-

nally through spraying, dipping, or painting. Detection is usually accomplished with a portable survey Geiger counter.

A thorough knowledge of the fate of incorporated insecticides is necessary for their safe and effective use. Radioisotopes provide a valuable method for studying their metabolic fate because of the ease, rapidity, and sensitivity of the method. Dieldrin, a widely used insecticide, is toxic to animals and there have been some cases of human poisoning. Its mechanisms of action is largely unknown but in experiments with mice injected with radioactive Dieldrin, there was a high concentration of activity in the liver with little excretion. Radioisotopic techniques employed with ^{32}P labelled Dipeux, a herbicide, have shown that resistant fly strains are able to detoxify the insecticide and excrete water soluble metabolites at a more rapid rate than normal susceptible flies.

The utilization of radioisotopes in animal nutrition and physiology has been enormously varied. Isotope experiments carried out on goats have shown with chromatography that at least 70 % of the glutamine, glutamic acid, leucine and tyrosine residues of casein and 50 % of the proline and asparagine residues come from free amino-acids of the blood and not from labelled plasma proteins. Column chromatography and various counting techniques have been utilized to show that in the biosynthesis of milk the composition of some of its amino-acids can be regarded as resulting from microbial synthesis in the rumen. The metabolic utilization of inorganic dietary selenium- ^{75}Se and arsenic has been shown to be related to sperm physiology ; both have been shown to be incorporated into DNA and protein of sperm, with a Geiger-Mueller detector analysing for the selenium- ^{75}Se and activation analysis employed for determining the arsenic.

The utilization of radioisotopes are heavily employed in the medical and pharmaceutical fields. The most common diagnostic use of radioisotopes in use today involves the use of radioiodine to assess the thyroid functions in adults. The test is performed by giving the patient a small oral dose of radioactive iodine, generally ^{131}I and 24 hours later measuring the percentage of the administered dose that now reaches the thyroid. While ^{131}I is both a β - and γ -emitter, only the latter can be accurately detected using a scintillation detector. A "picture" of the radioactively distribution within the gland can also be gotten by use of a scanning device, revealing whether there exist rather unusual concentrations of radioiodine, "hot" spots, or areas devoid of iodine, "cold" spots, which when correlated with other clinical data provide insight with respect to tumor pathology or other thyroid disorders. The routine therapeutic diagnostic test now consists of the patient swallowing a certain amount of aqueous iodine- ^{131}I : a blood sample is taken just prior to ingesting the iodine and then another sample two hours later to determine that the radio-active iodine has entered the blood. Twenty-four hours after ingesting the iodine the patient's activity in the area of his throat is determined. A "picture" is made of the patient's thyroid by a scanning machine having a moving probe which traverses back and forth a few centimeters above the patient's throat in the area of his thyroid gland. The probe is sensitive to the emitted radiation and it records on a piece of paper the distribution pattern of the radio-active iodine incorporated into the thyroid.

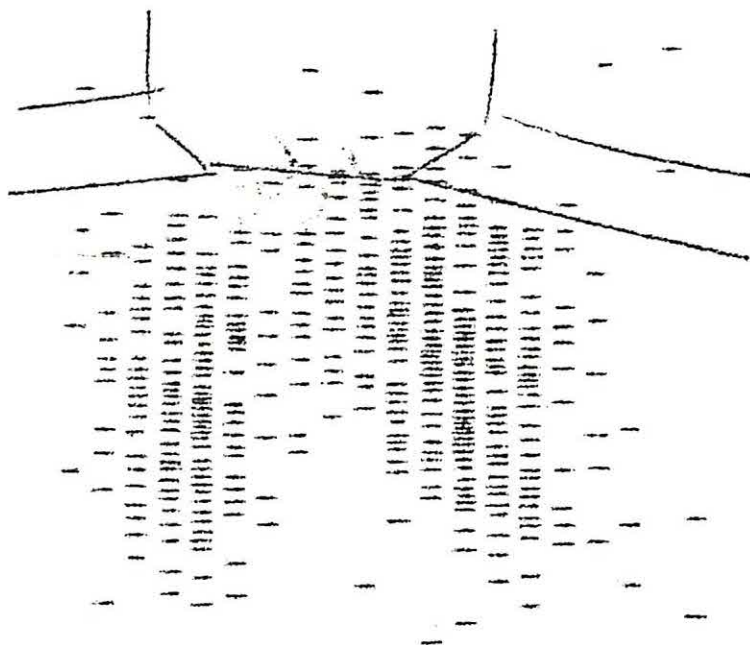


Fig. 5.- Typogram of a normal thyroid.

Figure 5 is an actual thyrogram and is an indication of the amount of radioactivity present and of its distribution pattern ; the thyrogram gives the physician a very good indication of the functional activity of the thyroid gland as to whether or not any disorders are present. Radioactive compounds have also found wide application in organ scanning due to chemical localization by a variety of physiological mechanism. Blood pools can be scanned with labelled albumin, and mercurials are effective kidney agents because of binding to the large number of exposed sulphydryl groups there. Abnormal permeability allows for the localization of brain tumours by some agents and pancreas and bone scanning can be done with gamma-emitting metabolites. The search for useful pharmacological agents has similarly been advanced by the application of tracer techniques in identifying pharmacologically active metabolites . Before the availability of isotope-labelled proteins, investigations of protein metabolism were largely based on nitrogen-balance studies but now such categories as rate of synthesis and degradation, steady-state conditions, and metabolic pathways can be elucidated.

The wide-spread use of tritium in biological studies has become important because of the ease with which a large number of metabolically active compounds such as hormones, vitamins, and other important or-

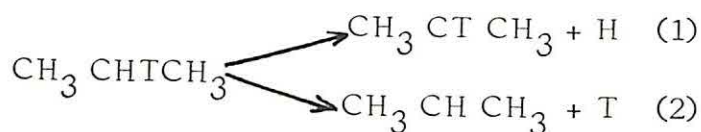
ganic constituents in the living cell can be labelled with tritium. Tritium (^3H) is playing a vital role in many investigations and special mention should be made of this widely utilized weak beta-emitter : it has been especially useful in making autoradiographs of tissues and single cells for purposes of localizing the tracer within the system. Figure 3 shows labelled human amnion cell nuclei and Figure 4 illustrates labelled chromosomes, particularly the labelling of individual chromatids. These autoradiographs demonstrate quite clearly the ease with which the labelled substances can be localized within the cells by standard autoradiographic techniques. Tritium labelling can also be combined with electron-microscope techniques for similar studies with ultra-thin sections.

The relationship between cellular deoxyribonucleic acid (DNA) content, nuclear volume, and the minimum mitotic cell cycle time of several plants has been investigated with tritium-labelled thymidine, a precursor of DNA. The method used was to treat the cells at different time intervals with the radioactive precursor and then with standard autoradiographic techniques look for labelled cell nuclei. Labelled cells were found only when DNA synthesis occurred, and that this synthetic period (S) was preceded by a pre-DNA (G_1) and post-DNA synthetic (G_2) phase, with mitosis then following the latter. The cell cycle time could be estimated by the rhythmic appearance and disappearance of the number of labelled cells in mitosis with time, and the duration of the mitotic cycle was taken to be the interval of time between two successive ascending portions of such a plot. Cell cycle times have been shown to vary from as few as 9 hours to several days and months, depending upon the physiological state of the organism and the amount of DNA to be synthesized : the cycle duration increases with DNA content and nuclear volume per cell.

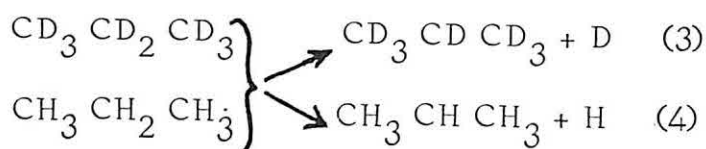
The question of the cellular and humoral mechanisms of action involved in bone marrow transplantation is still under discussion and radioisotopes are being employed in studying these important haematopoietic phenomena. Bone marrow transplantations have been successfully used in treating certain forms of whole-body radiation damage and labelled chemicals (tritiated thymidine and ^{14}C -glycine) have been employed in estimating the viability of bone marrow stored under different conditions obtained for therapeutic purposes : the number of labelled cells decreases with increase in time after storage : such studies are necessary in order to know how long bone marrow material can be stored for future use. The metabolism and distribution of tritium-labelled RNA precursors has been studied in patients with chronic leukaemia in order to gain some information about the cellular features of this malignant disease. Tritiated thymidine has also been used in patients with acute leukaemia to demonstrate that there are two types of cells (dividing and non-dividing) in the patient. Such types of research are seeking to understand the difference between "normal" and abnormal haematopoietic blood diseases or developing more efficient therapeutic procedures.

Tritium has also played a significant role in distinguishing intra- and intermolecular effects of various irradiated compounds. Radiolysis involves the breakage of bonds and the production of hydrogen. For some compounds, however, the hydrogen results in a highly selective manner from particular hydrogen bonds and the tracer technique can be used to

indicate molecular specificity. Consider the following example of an irradiated 3-carbon compound that is labelled with one tritium atom at its no. 2 carbon atoms :



If only hydrogen is produced (1) then it can come from only an hydrogen bond : if solely tritium (2) then from only the tritium bond. This sort of data gives information about intramolecular bonding properties. If a similar experiment is then run but with a mixture of a completely labelled deuterated compound with a non-deuterated compound



one can analyse for the production of deuterium (3) or the production of hydrogen (4). This type of experiment allows for some comparison between competitive primary and secondary reactions and intermolecular and intramolecular effects.

In conclusion it seems appropriate to state that there is no real physical obstacle to the wide spread use of nuclear energy techniques in biological research. To be sure, there are certain safety and shielding procedures that must be rigidly adhered to but for the beginner there are a large number of training centers, courses, books and experienced personnel which are available and which are sponsored by a variety of governmental and private organizations. A broad variety of radioactive chemicals, procedures, and equipment are available and the interested uninitiated scientists or student will be quickly rewarded by spending the time and effort to acquaint himself thoroughly with the various radioisotopic techniques that pertain to his research interests. To the neophyte scientist radioisotopic techniques may seem mysterious, full of gadgetry and a fad but to the experienced biologist radioisotopes can play an important role in his research programme and be used for furthering scientific knowledge.

TABLE I

A list of some radioactive isotopes commonly used in biological research, their radioactive half-life and type of radiation emitted.

<u>Isotope</u>	<u>Radioactive Half-Life</u>	<u>Type of Radiation emitted</u>
^3H (tritium)	12.4 years	β -rays
^{14}C Carbon	5568 years	β -rays
^{18}F Fluorine	112 minutes	β -rays
^{24}Na Sodium	15 hours	β, γ -rays
^{32}P Phosphorus	14.3 days	β -rays
^{35}S Sulphur	87.1 days	β -rays
^{59}Fe Iron	45.1 years	β, γ -rays
^{60}Co Cobalt	5.25 years	β, γ -rays
^{90}Sr Strontium	28 years	β, γ -rays
^{131}I Iodine	8.04 days	β, γ -rays

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The use of Radioisotopes in Biology

Morton W. Miller

Résumé

L'auteur de cette brève étude présente au lecteur un résumé des propriétés physiques et chimiques des radioisotopes et des tendances déjà nombreuses et très prometteuses concernant leur utilisation dans les différentes branches de la biologie. La plupart des propriétés des radioisotopes sont semblables à celles des isotopes stables correspondants, mais à la différence de ceux-ci, ils émettent de l'énergie sous forme de rayonnements qui peuvent être décelés au moyen d'appareils appropriés, ce qui a pour conséquence de révéler la présence et de suivre les déplacements d'un élément donné.

Grâce aux très grandes sensibilité et précision des détecteurs actuels, il est possible de n'employer avec succès que des quantités minimes de radioisotopes pour résoudre un grand nombre de problèmes de recherche biologique. Les radioindicateurs ont trouvé des applications importantes dans des travaux de recherche biologique très divers allant de la détection d'insectes marqués dans les arbres, à la localisation de substances particulières à l'intérieur de la cellule. Les différents domaines dans lesquels les radioisotopes ont été appliqués comprennent la biochimie, la physiologie, la microbiologie, la génétique, l'immunologie, la cytologie, et beaucoup d'autres branches de la biologie.

Resumen

La finalidad de este breve estudio es facilitar al lector un resumen de las propiedades físicas y químicas de los isótopos radiactivos y de las atractivas y fecundas perspectivas que ofrece su aplicación en las distintas ramas de la biología. Los isótopos radiactivos son átomos que poseen propiedades análogas a las de los correspondientes átomos estables, no radiactivos, con la excepción de que emiten energía en forma de radiaciones que pueden detectarse mediante dispositivos apropiados, con lo que se pone de manifiesto la presencia o los movimientos de estos átomos.

Se pueden emplear con éxito cantidades mínimas de radioisótopos en una gran variedad de investigaciones biológicas, ya que los actuales instrumentos de detección poseen una extremada sensibilidad y exactitud. Los trazadores radiactivos han encontrado amplia aplicación en un gran número de problemas de investigación biológica, que se extienden desde la detección de insectos marcados en los árboles hasta la localización de sustancias específicas en la célula; entre los diversos campos en que se han empleado radioisótopos figuran la bioquímica, la fisiología, la microbiología, la genética, la inmunología, la citología y muchas otras disciplinas biológicas.

A BRIEF INTRODUCTION TO THEORETICAL TAXONOMY

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PROPER NAMES AND GENERAL NAMES

Taxonomy is the study of the classification of organisms. One sometimes hears expressions of regret that we have to classify at all. But when the alternatives are realized, the necessity of classification for knowledge will be understood.

If we are to communicate, we must use symbols. The symbols which we rely on most for communicating what we would be prepared to call knowledge are words, though we do use numbers and could use them even more than we do. Words can be divided into two logical kinds: proper names, like Mount Everest, San Francisco, Lincoln; and general terms, like dog, red, quickly. The distinction being made is not a grammatical one; clearly, there are grammatically many more than two kinds of words, but logically there are just these two kinds: proper names and general (or common or class) names. Proper names are intended to name only one thing. General terms are intended to apply to more than one thing or instance. The presupposition is that things named by a general term have something in common, so that when one knows what "dog" means, one can apply the word to numerous canine animals, and know that these animals have something in common. There are certain traits had by dogs, so that the use of the word "dog" conveys some information. But if we know that something is called "Bobbie", this does not tell us anything. There are not traits a Bobbie must have, so the use of that name does not convey any information.

Proper names are individuals, and there are no criteria for a name's being given such that one could say a mistake was made if a proper name (e.g., a given name or a family name) were changed. General terms name groups or classes, and there are traits which serve as criteria for the applying of the term in particular cases.

If there were no general terms, i.e., if there were no symbols standing for classes, we would have only proper names and no classification (no named classes) and communication would be possible only to the extent that speaker and listener were both directly acquainted with the bearers of the proper names.

APPLIED TAXONOMY AND THEORETICAL TAXONOMY

The importance of the discipline that develops, clarifies, and criticizes classifications can hardly be over-rated. Taxonomy, concerned with classification of organisms, must not be neglected or slighted, for the biosphere would never have been ordered into knowledge without the products of the applied taxonomists (who are classifying particular kinds of organisms) and of the theoretical taxonomists (who are reflecting on theoretical questions of classifying).

Not every one who isolates a biological group, names it, and describes its traits, necessarily knows that he is doing taxonomy. And those who recognize the tasks and products of taxonomy, perhaps vaguely and imperfectly, do not necessarily realize the pervasiveness and fundamental importance of that discipline to knowledge.

It might be helpful to distinguish more explicitly between applied taxonomy and theoretical taxonomy. Applied taxonomy (by which we mean that it is concerned with practical decisions regarding the classification of particular organisms, not that it is unlike theoretical taxonomy in being applicable to organisms), is done by biologists who are primarily concerned with the taxonomic placement of particular organisms. They may be interested in the conceptual questions of theoretical taxonomy or they may prefer to leave the conceptual questions to the theoreticians. Theoretical taxonomy deals with the concepts or the philosophical grounds of classifying, rather than primarily with the classifying of particular organisms.

Following are selected writings on theoretical taxonomy, not cited elsewhere in the present text: Blackwelder (1967), Buck and Hull (1966), Cain (1962), Constance (1964), Ghiselin (1966a,b), Gilmour (1961), Hull (1965), Simpson (1961), Sneath (1964).

One might ask: why bother at all with the difficult conceptual questions of theoretical taxonomy? One reason might itself be practical, if we think more clearly about the conceptual foundations of classification, the actual particular taxonomic decisions will be better, because more carefully thought out and related logically to other decisions. Another reason is that theoretical taxonomy is an attempt to rationalize (in the sense of making rational) and to intellectually justify biological classifications, not merely in the sense of saying that the biological classifications work (in growing food, fur, controlling disease, providing raw materials, etc. - important as these practical results of biology are), but also that the biological classificatory claims are intellectually respectable. If biology is to count as knowledge, surely one must be able to say that it is true, i.e., logically valid and based on solid fact. Its methods and concepts must be justified.

In this essay, we shall offer no discussions regarding how particular organisms are to be classified. Rather, we shall limit ourselves to mentioning and briefly explaining some conceptual matters discussed by theoretical taxonomists, to which answers are either given in full awareness of at least some of the implications and difficulties, or answers are presupposed and left implicit possibly without our realizing that there

are alternative views or that such questions might even be raised. In addition, we treat briefly a few of the newer methodological developments in taxonomy.

TAXONOMY AND THE PROBLEM OF UNIVERSALS

Philosophers beginning not later than Plato have asked questions concerning the status of classes. In philosophy, this many-sided issue is called the problem of universals. A universal is that named by a general term, or that which applies to possibly many entities. "Possibly" is inserted because at a given point in time, say, when a new object has been invented or discovered so that there is then just only one specimen, the name of this thing applies actually to only one object, but it could and will apply to more things of the same kind. But we shall not linger over the problem of universals; it is only mentioned to show that taxonomy is a specification of the more general philosophical problem of universals which is concerned with non-organisms as well as with organisms.

This relationship prompts us to ask the questions: are there any significant differences between classifying non-organismic things and classifying organismic things? An affirmative answer is usually based on the fact that organisms reproduce and non-organisms do not reproduce. And if this emphasis is placed on the fact that organisms reproduce, one will probably be prepared to give a special place to the species out of all the taxonomic categories, especially if the biological concept of the species is followed. The biological concept of species looks on species as potentially or actually interbreeding populations capable of producing fertile offspring. It is, then, at the categorical level of species that the self-reproduction of organisms plays a part. Other categories are defined differently. One could almost say that one must be acquainted with a particular genus (or family or order ...) of bacteria or plants or animals before one can know what "genus" (or "family" or "order" ...) means.

There is, however, some relation between the higher taxonomic categories and what the course of evolution is believed to have been. That is, the higher taxonomic categories are determined in relation to evolutionary development and divergence, at least by one school of taxonomists.

NUMERICAL VERSUS PHYLOGENETIC TAXONOMY

There is presently a controversy in taxonomy between the traditional or phylogenetic taxonomists, those who would construct the classifications to show or reflect evolutionary development, and the numerical taxonomists, those who consider overall phenetic (as contrasted with genetic) similarity to be the only basis of classification. The numerical taxonomists allow that one may want to make claims about phylogeny (as well as overall phenetic similarity), but that if one makes phylogenetic claims, these must necessarily be made on the basis of phenetic similarities without weighting of important or significant organs or structures.

It is such weighting which the numerical taxonomists take issue with, feeling that there is something illicit in picking out certain organs or structures as phylogenetically significant, basing the classification on these organs or structures, and then bringing forth data concerning these organs in support of the classification, as if these data (and other comparable ones) had not been the basis of the classification in the first place. The numerical taxonomists would then be accusing the phylogenetic taxonomists of trying to give a misleading air of empiricalness to the classification, when it is actually an a priori and closed system.

The phylogeneticists reply that their method is the eminently respectable hypothetico-deductive one, according to which one offers an hypothesis, deduces what ought to be the case if the hypothesis were true, and gets confirmation or dis-confirmation for the hypothesis, and uses the confirmed hypothesis and the supporting evidence for it to formulate the next hypothesis (Hull, 1967).

The controversy between the phylogeneticists and pheneticists is a heated and even acrimonious one. One wonders if there is so much difference between them. A pheneticist may very well be interested in phylogeny; and surely a phylogeneticist is interested in phylogeny. Moreover, a phylogeneticist wants plenty of phenetic data. Perhaps the difference consists in how soon each is ready to construct a phylogeny. The pheneticists may want more data before he will begin. There are, of course, differences among the pheneticists; some want to say that even at the level of species, unweighted phenetic traits are to be used and, if interbreeding occurs and can be used as a trait, even interbreeding must be unweighted. This attitude disturbs the phylogeneticists.

If the classification produced by the pheneticists does not markedly differ from the classification produced by the phylogeneticists, even though their principles supposedly are seriously at variance, what ought we to conclude? That the quarrel between the pheneticists and phylogeneticists has no substance and is purely vacuous? Or that there is always, in the long run and overall, a necessary connection between the interbreeding of the members of a species and the high correlation of overall phenotypic traits?

SEXUALITY VERSUS ASEXUALITY IN TAXONOMY

The question of the biological species concept can only arise - naturally enough - in the case of sexually-reproducing organisms. For where there is no interbreeding, a classification cannot be based on interbreeding. One might then ask whether the same classifying principles can be applied to both sexually-reproducing organisms and organisms such as bacteria see Jacob and Wollman (1961) which are entirely or primarily asexually-reproducing.

While we are not yet ready to answer this question, it is itself puzzling that some kinds of organisms reproduce only sexually, other kinds reproduce only asexually, while still other kinds of organisms alternate,

regularly or irregularly, between the two modes of reproduction. One would think that, if there is (or are) any advantage(s) or disadvantage(s) of sexuality vis-à-vis asexuality, nature could have settled down to one way of organismic reproduction. It would seem that there has been enough time for evolution to decide the question ! But perhaps there hasn't been enough time to decide the most efficient way of getting new specimens in all cases. Or perhaps the most efficient way is to alter the mode of reproduction, according to the other traits of the organism and the environment. Or perhaps efficiency is not the primary value here, and nature permits as much variety as will do the job more or less well.

REMNANTS OF TYPOLOGY IN MODERN TAXONOMY

Most contemporary taxonomists explicitly repudiate any form of typology, a position at least some biologists think derives from Plato and Aristotle. There are some obvious features of typological thinking in biology which reflect certain points in the philosophies of Plato and Aristotle, but there are aspects of typological thinking in biology which would puzzle and revolt both of these philosophers. What typology essentially consists in is the view that for every class there is a fixed type. If we are to have knowledge, there is a type which we must have as the object of knowledge. One obvious difficulty with this view is that it seems to be inconsistent with evolution. If the type of any biological group is fixed, how can change occur. We cannot argue here the advantages of the Platonic or Aristotelian theories, nor the kinds of modifications in these theories needed to accommodate evolution, nor the theory which biologists do or can substitute for typology. Only what on one view may be judged to be a remnant of typological thinking will be briefly discussed here, namely, the type specimen ; a fuller treatment of the epistemological role and logical status of the type specimens is given by us elsewhere (Heise and Starr, 1968).

It is not the name alone, "type specimen", which recalls a theory of types. To avoid associations with typology, bacteriologists in their nomenclatural code, the International Code of Nomenclature of Bacteria (1966), call all of the nomenclatural types including the type specimen the "nomenifer" (literally, "name-bearer"). The type specimen is an example or instance of the class of organisms that the original investigator who names the species was working on. It is sure that this specimen is a member of that class. The type specimen differs from other instances of the class in that it is the authorized or "official" instance of that class, and, consequently, a species bears that name, or a synonym, as long as and only if the nomenifer is included in the species. Other members of that species might get a new name, say, in the case in which one species was later found to be made up of two species. Then some of the members of the original species would get a new name when the species is divided, but the type specimen of the original species keeps the original name of the species. The type specimen or nomenifer thus is the name - bearer (which is what "nomenifer" means), or perhaps one would want to say that the same is associated with the type specimen as we have recommended elsewhere (Starr and Heise, 1968b).

What one should avoid is a connection stronger than "associated" between the name of the class and the type specimen. "Attach" is the word which is used presently in their nomenclatural codes by the botanists and bacteriologists, but it seems to us to be seriously misleading. "Attach" suggests that the scientific name of the species is given only to the type specimen. Consequently, it would be a proper name which names just that individual, and therefore would be scientifically useless since we cannot draw any well-founded conclusions regarding the bearer of a proper name and any other entity. (Just because one Bobbie of our acquaintance has dark eyes does not mean that any other Bobbie must have dark eyes). If the species name is attached only to the type specimen, it is a proper name and unhelpful in advancing knowledge.

On the other hand, if the name is attached to the type specimen more closely than to any other member of the species, but not quite so closely as a proper name is attached to an individual, then we would have a hold-over from typological thinking. The type specimen is then viewed as embodying the type (of the species) or typifying the species. But neither of these approaches will do either, since a type (if it is anything like a Platonic Form or a form of the Aristotelian sort) is not anything which could be embodied by one instance of the class. Nor do most scientists think that the characteristics of the class could be embodied in one instance of that class. "Typifying" will not do either, since when the type specimen is chosen, knowledge of the species is incomplete, and the original investigator could not know whether the type specimen is typical or not, though in all probability he will pick as type specimen an instance typical of his array of specimens.

OSTENSIVE DEFINITION AND THE LOGICAL STATUS OF NOMENIFERS

The type specimen is an instance of the class. It is a sure instance of the class, but it is not more an instance of the class than the other members (which is what "embody" and "typify" imply). It has no special status, except that its name is assured. We might say that the type specimen is an ostensive definition of the species name, i.e., it is a concrete example of the class that can be pointed to when someone asks what that species name means. Alternatively, we might say that the type specimen has no privileged logical status since it is a member of the class just like any other member of the class just like any other member of the class; its epistemological (pertaining to our way of knowing) status is privileged to the extent of (a) our being sure that it (the type specimen) is a member of the class (of which it is the type specimen), and (b) our using the type specimen to ostensively define the name of the species.

By itself, the type specimen cannot show what traits are to count as class-defining. It cannot, on the one hand, because the type specimen may not be typical of the class, as has already been pointed out. On the other hand, the type specimen shares the shortcomings of all instances of ostensive definitions in not being unequivocal in respect to the properties being exemplified nor in making explicit which of the properties being exemplified is or are significant.

A simple example may make clear these two difficulties. Someone, probably a child, asks, "What is red?" "Red" is ostensively defined for him by his being shown a red object (the problems obtain no matter what object is chosen, so it does not matter which we choose), suppose it is an apple, and being told "That's red". What the person working out the meaning of the word has to do is pick out which property (or properties) are being pointed at. He might think it was the shape, or the smoothness, or the kind of fruit. That is the first problem with any instance of ostensive definition. The second difficulty with any case of ostensive definition can also be shown with our "red" example. Suppose the learning person somehow picks out the color of the apple as the property being pointed to, then the question must arise concerning the range of colors which can be covered by this word, "red". Let's say the red of the apple is a clear blue-red; should he or should he not include pink, red-orange, orange, magenta, red-violet, purple? What about variations of saturation and brilliance? The person learning the meaning of "red" can ask for many examples of what will count as red so that comparisons and corrections will eventually in most cases get him to the right concept, but the biologist trying to learn the meaning of a species name has only one example. Because a single instance of ostensive definition is not enough, and because it is hardly feasible to put on file the hundreds of thousands of specimens that would be needed if the name of the species were to be defined only ostensively, descriptions (or intensional definition) must also be used. So the investigator states in the original, naming publication the organism's characteristics as well as an appraisal of the importance of various traits. Such description and evaluation are offered by the original investigator, and are added to and amended by subsequent investigators.

TRAITS AND TAXONOMY

Deciding which traits are necessary for a class is one of the stickiest problems for practicing taxonomists. One refinement in the technique of choosing class-defining traits is the move from monothetic to polythetic classifications. The important difference between a monothetic classification and a polythetic classification is that in a monothetic classification a single trait or a set of traits is said to be necessary and sufficient to determine class membership, whereas in a polythetic classification no one of the set of traits is necessary but a proportion of the set is both necessary and sufficient to determine class membership see Beckner (1959), Sneath (1962), Sokal and Sneath (1963). But, unless - as is clearly not possible - one could use, as a basis of classifying, all traits of the organisms being grouped, which traits should be used can always be disagreed upon. To offer a polythetic classification, though the technique is indeed a refinement, does not obviate the problem of which set of traits is to be used, since the method of polythetic classification does not make any easier or more obvious the selecting of the traits that are to be class-determining. It might look as if one investigator say - on the basis of traits-set A - that group x is more like group z; and as if a second investigator says - on the basis of traits-set B - that group x is more like group z and less like group y. These disagreements are resolved (to the

extent that they are) by continued, careful gathering of data and analysis by competent investigators. (see Starr and Heise (1968a) for further treatment of this subject .

Considering the differences in their objects of study, it is hardly surprising that there are differences in the traits and methods used by taxonomic zoologists, botanists, and microbiologists. All three kinds of biologists can use morphological traits of the organisms which they study. Morphology may include traits as disparate as color, size, stainability, shape, and texture. All of them may similarly use biochemical, physiological, and serological properties of the organism.

But in order for a biologist to use behaviorail traits, what he is studying must behave. It can be said with fair assurance that animals behave, and behaviorial traits are indeed important in classifying animals. It is probably a peculiar plant or microbe that could be said to behave in any distinctive way useful for classifying, so that - on the whole - botanists and microbiologists cannot rely on behaviorial traits for classifying. Exceptions are known ; for example, the distinctive predatory behaviour of Bdellovibrio bacteriovorus (Stolp and Starr, 1963 ; Starr and Baigent, 1966) is a primary taxonomic feature of these tiny bacteria which are predatory parasites of other bacteria ; some of the tropic responses of plants and bacteria also might be mentioned as exceptions.

Relations to other organisms - which constitute part of the subject of ecology - might also be included in the list of properties useful in classifying. For example, some organisms are parasites of others ; sometimes, the parasite devours the host (as in the case of Bdellovibrio bacteriovorus mentioned above) or else the host is caused to produce more of the parasite which cannot alone reproduce itself (as in the case of bacteriophage).

BACTERIOPHAGE AND BACTERIAL TAXONOMY

Bacteriophage (or phage) are a special group of viruses for which bacteria serve as the host organism. Probably every known kind of bacterium has one or more phage parasites, although only relatively few of them have been studied. It might be useful to review briefly the nature of phages and of their reactions with bacteria because the interaction is used in classifying both bacteria and phages.

A typical phage particle consists of a head and a tail. The phage head consists of a tightly packed core of a tightly packed core of nucleic acid (usually DNA but, in a few cases, RNA) surrounded by protein. The head is frequently hexagonal in cross-section, though other shapes are known ; a common size is about 65 m μ in diameter (range 25-100 m μ). The phage tail varies in size and complexity , and may be absent from some phages ; it may consist of a hollow core surrounded by a contractile sheath, and it may terminate in a base-plate (which may have tail fibers attached) or in a knob.

Bacteriophage interact with bacteria in a number of ways : when an uninfected phage-sensitive bacterium is exposed to phage, infection usually will take place. The phage is absorbed into the cell surface (at specific receptor sites) and the nucleic acid of the phage is injected through the phage tail core into the bacterial cell, perhaps by contraction of the contractile sheath of the phage. This injected phage nucleic acid may now be replicated within the bacterial cell and mature by acquiring protein coats, after which the host bacterial cell lyses and free phage is liberated. As an alternative to producing a lytic infection, many phages (called "temperate") can attach to the bacterial chromosome and reproduce synchronously with it. The bacterium is now lysogenic ; that is, it bears a latent temperate phage which sometimes detaches from the bacterial host's chromosome, multiplies within and lyses its host, behaving as infective phage.

As might be surmised from the intimate relationship , phage-host reactions are frequently rather specific ; that is, a given phage preparation can usually attack only a limited group of closely related bacterial strains. For this reason, phage-host reactions are quite useful in bacterial taxonomy and identification (Meynell, 1964 ; Dye, Starr, and Stolp , 1964 ; Stolp and Starr, 1964 ; Stolp, Starr, and Baigent, 1965) ; They are useful traits in classifying phages, too.

THE GENETIC CODE AND TAXONOMY

The newest and most exciting frontier in taxonomy is the possibility of reading the genetic code itself . Biological classification could then be based on direct measurements of the genetic material, as distinct from the indirect knowledge presently available through observing the phenotypic expression of the genes. When such measurements become technically feasible, one might determine directly the degree of similarity of the genetic material - the deoxyribonucleic acids (DNA) - between organisms which can interbreed and produce fertile offspring ; this degree of similarity might then constitute a calibration for the species level . Lesser degrees of similarity might be used to decide other taxonomic levels, which might or might not coincide with current genera , families, orders, etc.

We are technologically still some distance away from this ideal ; however, there have recently been interesting findings on the relationships of DNA-base ratios and of DNA homology to the classification, at first, of bacteria and other microbes and, currently, of higher organisms as well.

The methods used for determining DNA-base ratios involve either a rather tedious direct chemical measurement of the content of the individual bases in the DNA or an indirect measurement (usually based upon the thermal denaturation temperature or the density found in a CsCl gradient) which had previously been calibrated against a direct chemical determination. Extensive reviews on this subject have been presented by Marmur, Falkow, and Mandel (1963) ; Rosypal and Rosypalova (1966) ; Mandel and Marmur (1968) ; and others.

Let us turn here to considering, in a highly simplified and didactic format, the taxonomic implications of DNA-base ratios. A remarkably constant ratio of guanine-plus-cytosine to adenine-plus-thymine (usually expressed as molar percentages of G+C) is found in those individuals which are considered on other bases to belong to the same species [see Mayr (1966) ; Ravin (1960, 1963) ; and literature cited therein, for the meaning(s) of "species"] . Moreover, there is a relatively narrow range of G+C values for the species which are considered on other bases to belong to the same genus see Starr and Mandel (1968) for an example pertaining to the phytopathogenic bacteria of the genus Erwinia . Two organisms with significantly different base ratios are usually considered not to be closely related taxonomically . Two organisms with similar base ratios may be related taxonomically ; on the other hand, it is very important to realize that they may indeed not be related taxonomically, since the methods being used disclose only the relative amounts of the four bases and tell us nothing about the sequence of the individual bases in the DNA.

Somewhat closer in principle to the ideal of determining directly the actual sequence of the bases in the DNA ("reading the genetic code") are the various methods of determining the relatedness ("genetic homology") between two single-strands of DNA from two different organisms. Though considerable improvement in methodology is necessary before such direct measures of the genetic homology will be routinized, information likely to be of considerable interest to taxonomists has already been obtained by the pioneers in this field (McCarthy and Bolton, 1963 ; De Ley et al, 1966 ; De Ley and Park, 1966 ; Brenner, Martin and Hoyer, 1967).

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A Brief Introduction to Theoretical Taxonomy

H. Heise and M.P. Starr
(Résumé)

La taxonomie a pour objet la classification des organismes (il n'y a pas de connaissance possible sans classification).

On distingue la taxonomie fondamentale et la taxonomie appliquée ; le propre de la taxonomie fondamentale est la justification des méthodes de classification. Elle permet une application raisonnée.

La taxonomie apparaît comme une branche du système des "Universaux" ("universel", nom sous lequel les philosophes désignaient les termes généraux qui servaient à classer les organismes et les idées). Mais il apparaît une différence entre la classification du vivant et la classification du non-vivant, les premiers seuls se reproduisent d'où la notion d'espèce.

Il existe deux sortes de classifications : la taxonomie numérique, tenant compte des similitudes et des traits caractéristiques et la taxonomie phylogénétique, basée sur l'évolution organique. Bien que les bases diffèrent, ces deux classifications sont voisines.

Mais peut-on appliquer les mêmes principes de classification aux organismes sexués et asexués ?

La typologie qui veut qu'à chaque classe corresponde un type déterminé, ne fait pas de part à l'évolution et est refusée par de nombreux taxonomistes. Seul subsiste la notion de spécimen-type, c'est le membre officiel d'une classe donnée (il n'en est pas représentatif) ; il n'indique aucunement quels traits précis distinctifs font qu'il appartient à cette classe d'où la nécessité d'une description supplémentaire.

On peut encore distinguer la classification "monothétique" où un simple trait ou groupe de traits suffisent pour déterminer la classe et la classification "polythétique" où c'est le rapport des traits les uns par rapport aux autres qui interviennent.

Les bases de la classification peuvent différer entre Botanistes, Zoologistes et Microbiologistes (bactériophages classés d'après la spécificité de leurs hôtes). La classification idéale serait celle basée sur le code génétique et le rapport des diverses bases entre elles.

Breve introducción a la taxonomía teórica

H. Heise y M.P. Starr

(Resumen)

La taxonomía tiene por objeto la clasificación de los organismos (no hay conocimiento posible sin clasificación).

Puede distinguirse la taxonomía fundamental y la taxonomía aplicada ; lo propio de la taxonomía fundamental es la justificación de los métodos de clasificación, lo que permite su aplicación razonada.

La taxonomía constituye una rama del sistema de los "universales" (nombre con que los filósofos designaban los términos generales utilizados para clasificar los organismos y las ideas). Sin embargo, hay una diferencia entre la clasificación de lo viviente y de lo no viviente, pues sólo los seres de la primera categoría se reproducen, de lo que se deriva la noción de especie.

Hay dos clases de clasificaciones : la taxonomía numérica, que tiene en cuenta las semejanzas y los rasgos característicos, y la taxonomía filo-genética, basada en la evolución orgánica. Aunque sus fundamentos difieren, esas dos clasificaciones son muy afines.

Cabe preguntarse si es posible aplicar los mismos principios de clasificación a los organismos sexuales et asexuales.

La tipología que asigna a cada clase un tipo determinado, no tiene en cuenta la evolución y es rechazada por numerosos taxonomistas. Sólo subsiste la noción de ejemplar tipo como miembro oficial de una clase dada (pero sin carácter representativo) y sin que ello indique cuáles son los rasgos distintivos precisos que le hacen pertenecer a esa clase, lo que obliga a dar una descripción suplementaria.

Se pueden también distinguir la clasificación "monotética", en la que un simple rasgo o grupo de rasgos basta para determinar la clase, y la clasificación "politética" en la que intervienen las relaciones de unos rasgos con respecto a otros.

Las bases de la clasificación pueden diferir entre los botánicos, los zoólogos y los microbiólogos (bacteriófagos clasificados con arreglo a la especificidad de sus huéspedes). La clasificación ideal sería la fundada en el código genético y en la relación mutua de las diversas bases.

The Role of Systematics in Biology

The study of all aspects of the diversity of life
is one of the most important concerns in biology.

Ernst Mayr

There are many ways of dealing with the topic that was assigned to me. One might give a history of the role which taxonomy has played in the development of biology; or one might concentrate on the present status of systematics in biology; or finally one might attempt, in a timeless and somewhat philosophical way, to delineate the niche which systematics occupies within the total conceptual framework of biology. Further thought makes it evident that the three approaches are interdependent to such a degree that one has to give due consideration to all three of them.

Let me start with the question, what

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do we mean by "systematics," the role of which I am to describe? To be able to answer this question meaningfully requires an excursion into the history as well as philosophy of biology. The ancient Greeks saw a natural order in the world which, they thought, could be demonstrated and classified by certain logical procedures. They tried to discover the true nature of things (their essences) and approached classification with the methods of logic. Indeed, Aristotle, the first great classifier, was also the father of logic. The underlying philosophy, now usually referred to as essentialism (from essence), dominated the thinking of taxonomists up to and including the time of Linnaeus. Taxonomic nomenclature and the so-called typological thinking of taxonomists right up to our day have been permanently affected by the Aristotelian heritage (1).

History of Taxonomy

During the early history of biology this was no great handicap. Botany and zoology, to state it in a highly oversimplified manner, arose from the 16th century on as applied sciences, attached to medicine. Botany started as a broadened study of medicinal herbs and early botanical gardens were herb gardens. With but one or two exceptions all the great botanists and herbalists from the 16th to the 18th century (Linnaeus included) were professors of medicine or practicing physicians. Zoology arose in connection with human anatomy and physiology. When botany and zoology became independent sciences, the first concern of the two fields was to bring order into the diversity of nature. Taxonomy was therefore their dominant concern, and indeed in the 18th and early 19th century botany and zoology were virtually coextensive with taxonomy. Moreover, by sheer necessity, taxonomy was essentially the technique of identification.

The middle third of the 19th century was a period of decisive change to which many separate streams of development contributed. Increasing professionalism was one, and increasing specialization was another, to mention just two. Taxonomy itself helped in accelerating the change by introducing several new concepts into biology. The greatest unifying theory in biology, the theory of evolution, was largely a contribution made by the students of diversity, as we might call the taxonomists. It is no coincidence that Darwin wrote his *Origin of Species* after encountering taxonomic problems dur-

ing the voyage of the *Beagle* and after 8 years of concentrated work on barnacle taxonomy. The comparison of different kinds of organisms is the core of the taxonomic method and leads at the same time to the question how these differences originated. The findings of explorer taxonomists, paleotaxonomists, and comparative anatomists inexorably led to the establishment and the eventual acceptance of the theory of evolution.

One might have expected that the acceptance of evolution would result in a great flowering of taxonomy and its prestige during the last third of the 19th century. This was not the case, in part, one might say, for almost administrative reasons. The most exciting consequences of the findings of systematics were studied in university departments while the very necessary but less exciting operations of descriptive taxonomy, based on collections, were assigned to the museums. Furthermore, most taxonomists were satisfied to use evolutionary concepts for rather practical purposes, such as evidence on which to base inferences on classification. As a consequence, evolutionary biology did not contribute as much to the strengthening of the bridge between taxonomy and other branches of biology as one might have expected. The great contributions to biology made by taxonomists during this period, such as population thinking, the theory of geographic speciation, the biological species concept, and several others that I shall mention presently, were incorporated into biology anonymously and without taxonomy receiving due credit.

Biology is no exception to the well-known phenomenon that in science there is a continuous change of fashions and frontiers. Since the 1870's there has been one breakthrough after another, beginning with the improvements of the microscope and the exciting discoveries of cytology. Perhaps the dominant trend during this period was an increasing interest in biological mechanisms, and in the chemical-physical explanation of biological functions. This led to the flourishing of various branches of physiology, of endocrinology, of genetics, of embryology, of immunology, of neurophysiology, of biochemistry, and of biophysics. Taxonomy, the oldest and most classical branch of biology, inevitably suffered in competition with all these brilliant developments. Whenever there was an interesting new growing point in taxonomy, it quickly made itself independent and left a rather de-

scriptive, static, and sometimes almost clerical residue behind. The older ones among us remember the days when taxonomy was regarded by most biologists as an identification service. Some of the best universities in this country refused to accept Ph.D. theses in the field of taxonomy. The Guggenheim Foundation was the only granting agency that considered taxonomy worthy of support. Under the circumstances it was not surprising that only the most dedicated naturalists would choose taxonomy as their life's work, and we must pay tribute here to some inspired teachers who attracted gifted youngsters into our field.

Even today systematists feel that they are not getting their full share of recognition, of adequate financial support, and of truly superior graduate students, yet one must recognize that the change for the better in the last 20 or 30 years has been quite dramatic. This change had many causes but for some aspects it is not easy to say what is cause and what is effect. Taxonomists played a decisive role in the development of the synthetic theory of evolution, and this is being increasingly recognized by the leaders of biology. Julian Huxley and others have emphasized that taxonomy is indeed a vital branch of biology. Simultaneously we have witnessed a steady improvement in the scientific training of taxonomists. In order to obtain a position it is no longer sufficient that the young taxonomist knows how to describe new species; he is now expected to have acquired an adequate training in, and understanding of, genetics, statistics, animal behavior, biochemistry, and other branches of experimental-functional biology. The bridge between museums and universities is being broadened and strengthened in most places and the strong barriers between a narrowly defined taxonomy and the adjacent branches of biology are being obliterated. This new generation of taxonomists is no longer satisfied to work on preserved specimens. This new breed of naturalist-taxonomists insists on studying taxa as living organisms and pursues such studies in the field and in the experimental laboratory, wherever such studies will be most productive.

The ultimate result of these developments has been the general recognition that the universe of the taxonomist is far greater than was previously envisioned. Taxonomists now take an ever-increasing interest in evolutionary, ecological, and behavioral research, and

indeed have assumed leading roles in these fields. Up to recently the terms *taxonomy* and *systematics* were generally considered to be synonymous. In view of the recent developments it seems advantageous to restrict the term taxonomy to the theory and practice of classifying, more narrowly defined, and to make use of the term systematics for the study of organic diversity, more broadly defined. This new viewpoint is represented by Simpson's definition (2): "Systematics is the scientific study of the kinds and diversity of organisms and of any and all relationships among them." In short, *systematics is the study of the diversity of organisms*.

When I was assigned the topic of my presentation I took it for granted that I should adopt his broad definition. The lectures and discussions during this conference have confirmed that this is indeed the definition of systematics which is adopted by the current leaders in the field. But there is one additional reason why we should define systematics so broadly.

The Position of Systematics in Biology

When we look at biology as a whole we see that systematics occupies a unique position. Some years ago I pointed out that there are basically two biologies (3). One deals with functional phenomena and investigates the causality of biological functions and processes; the other one, evolutionary biology, deals with the historical causality of the existing organic world. Functional biology takes much of its technique and *Fragestellung* from physics and chemistry, and is happiest when it can reduce observed biological phenomena to physical-chemical processes. Evolutionary biology, dealing with highly complex systems, operated by historically evolved genetic programs, must pursue a very different strategy of research in order to provide explanations. Its most productive method is the comparative method, for which the taxonomists have laid the foundation. Indeed, I can hardly think of an evolutionary problem that is not posed because of some findings of taxonomy.

One can express these basic concerns also in a somewhat different manner. At one extreme of biology there is a preoccupation with the ultimate building stones and ultimate unit processes that are the common denominators throughout biology. This has largely

been the concern of molecular biology from the structure of macromolecules to such functional unit processes as the Krebs cycle. As legitimate as the reductionist methodology is when applied to functional problems, it quickly carries us down to a level where we leave behind most of that which is most typically biological, and we are left with a subject matter that is essentially physical-chemical. This is surely true for the chemistry and physics of the ultimate building stones and unit processes of living organisms. If this were the only level of integration in biology, it would be quite legitimate to combine biology with chemistry or physics.

The other extreme is the preoccupation with that level of biology that deals with whole organisms, with uniqueness, and with systems. It is a matter of historical record that taxonomists are among those biologists who have been most consistently concerned with whole organisms and who have most consistently stressed the organismic, the systems approach to biology.

No one will question the immense importance of molecular phenomena but they are not the only aspect of biology. As Michael Ghiselin has stated it so perceptively, just as architecture is more than the study of building materials, so is biology more than the study of macromolecules. In systematics, in evolutionary biology, and in much of organismic biology, one normally deals with hierarchical levels of biological integration that are many orders of magnitude above the molecular level. Each level has its specific problems and its own appropriate methods and techniques. That there is such a difference in levels of integration is completely taken for granted in the physical sciences. No one would expect the aeronautical engineer to base the design of airplane wings on the study of elementary particles. But a uniqueness of role for each level is even more evident for the different levels of biological integration.

Lest I be misunderstood, there is no conflict between molecular biology and organismic biology (including systematics). But it must be emphasized that each level of integration poses its own specific problems, requires its own methods and techniques, and develops its own theoretical framework and generalizations. This has been clearly recognized and frequently stated by the foremost leaders of molecular biology. Consistent with this is the fact that faculty and curriculum in the areas of

systematics, ecology, and evolutionary biology have recently been strengthened in several of the leading American universities, and as a result systematics has now become better integrated into biology than at any other time since the days of Darwin.

The role of systematics should now be quite clear: It is one of the cornerstones of all biology. It is the branch of biology which produces most of our information on the levels of integration, designated as natural populations and higher taxa. It supplies urgently needed facts, but more importantly, it cultivates a way of thinking, a way of approaching biological problems, which is alien to the reductionist, but which is tremendously important for the balance and well-being of biology as a whole.

Let me now turn to some of the concrete contributions made by systematics.

The Contributions of Systematics to Biology

The magnitude of the contributions made by systematics is not appreciated by many biologists. And yet these achievements are extraordinary indeed, even if we adopt the most narrow definition of taxonomy. They include the description of about one million species of animals and half a million species of higher and lower plants, as well as their arrangement in a system. This classification, much as we continue to modify it in detail, is on the whole amazingly logical, internally consistent and stable. It is an immensely useful system of information storage and retrieval. All the comparative work of morphologists, physiologists, and of phylogenetically inclined molecular biologists would be meaningless if it were not for the existence of the classification.

Taxonomists supply a desperately needed identification service for taxa of ecological significance and for the correct determination of fossil species needed for work in stratigraphy and geological chronology. In all areas of applied biology good taxonomy is indispensable, as in public health in the study of vector-borne diseases and of parasites; in the study of the relatives of cultivated plants and of domestic animals; and in the study of insect pests and their biological control. Much work in conservation, wildlife management, and the study of renewable natural re-

sources of all kinds depends for its effectiveness on the soundness of taxonomic research. The faunas, floras, handbooks, and manuals prepared by taxonomists are indispensable in many branches of biology and also widely used by the general public.

As important as these descriptive and service functions of taxonomy are, they are only part of the contribution of systematics, and to many of us the least important part, even though a prerequisite of all the others. I have pointed out already that the founding of evolutionary biology was the work of taxonomists. They also supplied the solution of many individual evolutionary problems. This includes the role of isolation, the mechanism of speciation, the nature of isolating mechanisms, rates of evolution, trends of evolution, and the problem of the emergence of evolutionary novelties. Taxonomists (including paleontologists) have made more significant contributions to all these topics than have any other kind of biologists.

There is hardly a taxonomic operation during which the systematist does not have to face basic biological questions. In order to assign specimens to species he must study variability and particularly polymorphism, and quite often he has to undertake a rather complete population analysis including the study of life cycles. In the study of polytypic species he concerns himself with geographic variation and its meaning; he studies the adaptation of local populations and tests the validity of climatic rules. When studying the population structure of species, he examines isolates and belts of hybridization. Indeed, taxonomists have developed in the last two generations a veritable "science of the species," as cytology is the science of the cell and histology the science of tissues. At every step he must think about the adaptation of populations, their past history, and the magnitude of dispersal (gene exchange between populations).

Many new concepts arose out of this work of the taxonomist but have since diffused broadly into genetics, ecology, physiology, and other areas of biology. By far the most important of these, as I have often stressed in the past, is population thinking. Biology, as all other sciences, was permeated by typological thinking until late in the 19th century, and is still today. When the learning psychologist speaks of *The Rat* or *The Monkey*, or the racist of *The Negro*, this is typological thinking. The

early Mendelians were pure typologists. A mutation changed The Wildtype, and the result was a new type of organism, according to De Vries a new species. I have pointed out elsewhere (4) that taxonomists began as early as the 1840's and the 1850's to collect large series of individuals, population samples as we would now say, and describe the variation of these samples. From this purely pragmatic operation emerged eventually a wholly new way of thinking which replaced typological essentialism. From taxonomy, population thinking spread into adjacent fields and was in part instrumental in the development of population genetics and population cytology. Population thinking has now spread into the behavior field, into physiology, and into ecology. This one conceptual contribution alone has been of such great benefit to vast areas of biology as to justify support for systematics.

As the interests of the systematists broaden, it is becoming more and more true that systematics has become, as stated by Julian Huxley (5), "one of the focal points of biology." Although he may not be able to solve these problems himself, it is the systematist who frequently poses the problems which are of concern to the population geneticist, the physiologist, the embryologist, and the ecologist. For instance, systematics poses the problems in that area of ecology which deals with the phenomena of diversity, the differences in the richness of faunas and floras in different climatic zones and habitats, and so forth. A succession of prominent taxonomists have been leaders in the study of problems of species competition, niche utilization, and structure of ecosystems.

Environmental physiology owes much to systematics. Zoological systematists like C. L. Gloger, J. A. Allen, and Bernhard Rensch have made major contributions to the discovery of adaptive geographic variation and the establishment of climatic rules. Up to the 1920's it was almost universally believed that geographic differences among populations of a species were nongenetic modifications of the phenotype and of no evolutionary interest. As it was stated, "the type of the species is not affected." It was zoologists with taxonomic interests or training who demonstrated the genetic basis for adaptive differences between geographic races. The stress of unique characteristics of individuals, the recognition of differences between

populations, the emphasis on the phenotype as a compromise between multiple selection pressures, all this represents thinking which came straight out of evolutionary systematics but has exercised and is continuing to exercise a profound influence on environmental physiology.

Applying taxonomic principles to the interpretation of man's evolution, as was done by Simpson, LeGros Clark, Mayr, and Simons, has decisively added to our understanding of man's evolution and of hominid classification. The chaos of 29 generic and more than 100 specific names caused by the earlier typological approach was replaced by a biologically oriented classification in which three genera, *Paranthropus*, *Australopithecus*, and *Homo* (the latter with two species), are recognized.

Whole branches of biology are unthinkable without systematics. Biological oceanography is one example, and biogeography another. This field has traditionally been the domain of the taxonomists to such a degree that it is unnecessary to stress the contribution of systematics. Cytogenetics and bioacoustics are other areas of biology that derived much of their inspiration from systematics. Systematists have enormously contributed to ethology through their comparative behavior studies, particularly of insects.

There are two reasons why it is necessary to stress these contributions. One is that those who have come into biology from the outside (for example, from physics or chemistry) simply do not know this history. The second reason is that there has been a tendency even among those who know the situation to credit all the neighboring fields, population genetics, ecology, or ethology, even though the advances were made by practicing taxonomists and were made possible only by the experience they had gained as taxonomists. It is totally misleading to limit the labels taxonomy or systematics to the purely clerical, descriptive operations and to give a different label to all the broader findings and concepts that are the direct result of the more elementary operations. Regrettably, even some taxonomists have supported the myth that all the more biologically interesting activities and findings of the taxonomist are not part of taxonomy. In this connection it will be of some importance, in order to clarify the situation, to add a few words on the structure of systematics.

The Structure of Systematics

In the earlier part of my discussion I described how systematics, as we now understand it, emerged from essentialism and nominalism (by rejecting these concepts) and became based on the fact of evolution. It began to study organic diversity as the product of evolution. It recognized that every classification is a scientific theory with the properties of any scientific theory: it is explanatory, because it explains the existence of natural groups as the products of common descent; it is predictive, because with high probability it can make predictions as to the pattern of variation of unstudied features of organisms and the placing of newly discovered species. Finally, systematics established many new contacts with other areas of biology by adopting the thesis that the characteristics of the living organism are at least as important for classification as those of preserved specimens.

How did these profound changes in the science of systematics affect its working procedure? In some ways not at all, because the needs for sound classification have not changed. There is still the same need to order the diversity of nature into elementary units, biological species. Sorting variable individuals and populations into species (and naming and describing them) is sometimes referred to as alpha taxonomy. There is still need for some alpha taxonomy even in as mature a branch of systematics as bird taxonomy. New species, new subspecies, and all sorts of new taxa of birds are still being found. We still discover occasionally that a species of the literature is nothing but a variant of another species. In ornithology we still are in need of compilations, checklists, and descriptive works of various sorts that fall under the designation of alpha or beta taxonomy. And yet even in these relatively elementary procedures of taxonomy there is a drastic difference between doing them either in a typological (=essentialist) or in a biological-evolutionary fashion.

The typologist acts as if he were dealing with the "essential natures" of created types. He stresses morphotypes and discontinuities; variation is treated as a necessary evil to be ignored as much as this is possible. The biological systematist knows that he is dealing with samples of variable natural populations; he is interested in the biological meaning of this variation. He

knows that he is dealing with living organisms and wants to study all their attributes whether they concern morphology, behavior, ecology, or biochemistry.

An understanding of the biological meaning of variation and of the evolutionary origin of groups of related species is even more important for the second stage of taxonomic activity, the sorting of species into groups of relatives ("taxa") and their arrangement in a hierarchy of higher categories. This activity is what the term classification denotes; it is also referred to as beta taxonomy. No matter how interested a taxonomist is in the evolutionary and ecological aspects of the taxa he studies, he will also devote a major share of his time to alpha and beta taxonomy, not only because so much work still remains to be done, but also because the more interesting biological problems are found only through research in alpha and beta taxonomy.

The Future of Systematics

I would feel rather pessimistic about the future of taxonomy if it were only an identification service for other branches of biology, as is thought by some of our less imaginative colleagues. But he who realizes that systematics

opens one of the most important doors toward understanding life in all of its diversity cannot help but feel optimistic. Environmental biology, behavioral biology, and even molecular biology are all moving in our direction. The most exciting aspect of biology is that, in contradistinction to physics and chemistry, it is not possible to reduce all phenomena to a few general laws. Nothing is as typically biological as the never-ending variety of solutions found by organisms to cope with similar challenges of the environment. Nothing is more intriguing than the study of differences between related organisms and the challenge to explain these differences as the result of natural selection. Even in cases where the ultimate solution may come from genetics or biochemistry, it is the systematist who in almost every case is the one who poses the challenging questions. The opportunities for exciting research are virtually unlimited. This is becoming clearer and more widely appreciated every year.

These opportunities are not without obligations. Let us remember at all times that each and every taxonomist is a spokesman for systematics. He must carry out his activities in such a way as to reflect favorably on his field. Let us remember that taxonomy is not a kind of stamp-collecting but a branch of biology. Let us desist from all prac-

tices that are injurious to the prestige of systematics, as, for instance, by indulging in nomenclatural practices that lower the value of scientific nomenclature as an information storage and retrieval system. Finally, let us remember that in virtually every taxonomic finding certain generalizations are implicit that are of value and broad interest to biology as a whole. It will help our relations with other branches of biology if we make these findings known. They are sure to have a minor or major impact well beyond the bounds of systematics.

It is my sincere belief, to summarize my discussion, that systematics is one of the most important and indispensable, one of the most active and exciting, and one of the most rewarding branches of biological science. I know of no other subject that teaches us more about the world we live in than systematics, the study of the diversity of life.

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The Role of Systematics in Biology

E . M a y r

(Résumé)

Rôle historique : jusqu'au début du 19^e siècle, zoologistes et botanistes utilisèrent la taxonomie pour ordonner le champ de leurs observations. Jusqu'alors simple technique d'identification, la taxonomie contribua largement à la naissance puis au développement de la théorie de l'évolution. Bien qu'on en ait longtemps fort injustement minimisé le rôle, il n'en demeure pas moins que l'univers du taxonomiste est vaste : la systématique est l'étude de la diversité des organismes.

Rôle biologique : il est deux sortes de biologies : l'une s'attache aux fonctions biologiques et s'efforce de réduire les phénomènes observés à certains processus physiques ou chimiques au niveau moléculaire ; l'autre s'intéresse aux organismes vivants dont elle tente de résoudre les problèmes d'évolution, grâce à l'interprétation de la systématique.

L'ampleur des contributions de la systématique à la Biologie est extraordinaire et demande à être mieux connue : elle s'applique à nombre de domaines très divers, allant de la génétique à l'embryologie en passant par l'évolution de l'homme ou l'écologie.

En fait la nécessité d'une saine classification demeure ; le point de vue n'est plus le même : l'évolution cesse d'être un obstacle, et devient centre d'intérêt.

La systématique est bien l'une des branches les plus riches, les plus passionnantes de la Biologie.

La función de la sistemática en la biología

E . M a y r

(Resumen)

Función histórica : hasta principios del siglo XIX, los zoólogos y los botánicos utilizaron la taxonomía para ordenar el campo de sus observaciones. Simple técnica de identificación hasta entonces, la taxonomía contribuyó considerablemente al nacimiento y después al desarrollo de la teoría de la evolución. Aunque durante largo tiempo se haya reducido injustamente su función, no cabe duda que el universo del taxonomista es muy vasto : la sistemática es el estudio de la diversidad de los organismos.

Función biológica : hay dos clases de biólogos ; los de la primera estudian las funciones biológicas y procuran reducir los fenómenos observados a ciertos procesos físicos o químicos en el nivel molecular ; los de la segunda se interesan por los organismos vivos a fin de resolver los problemas de su evolución mediante la interpretación de la sistemática.

La amplitud de las aportaciones de la sistemática a la biología es extraordinaria y merece ser mejor conocida : su aplicación abarca dominios muy diferentes, desde la genética a la embriología pasando por la evolución del hombre o la ecología.

Es evidente que persiste la necesidad de una adecuada clasificación aunque el punto de vista ya no es el mismo : la evolución deja de ser un obstáculo y se convierte en un centro de interés.

La sistemática es sin duda una de las ramas más ricas y apasionante de la biología.

HUDSON HOAGLAND

Mechanisms of Population Control

It is impossible for the thoughtful man to escape a certain ambivalence of response to the social impact of most great scientific discoveries. The unlocking of nuclear energy promises enormous potential benefits as a source of industrial power and as a servant of the medical sciences. But the rapid multiplication of nuclear bombs in the arsenals of growing numbers of nation states, uncontrolled by enforceable world law, may render man an extinct species. All organisms must adapt to the environments or perish. After Hiroshima, the notable change in our environment is that it now contains nuclear weapons, which have made obsolete not only traditional views of national sovereignty but traditional concepts of how the security of nations can be protected. The hope for man is that he can change his ways of thinking to cope with this new environment before it destroys him.

There are of course many other examples of antithetical applications of science. The automobile and the airplane are of great convenience in transportation, but the automobile kills 40,000 Americans a year, and the airplane overhead may be an enemy bomber. The knife is a tool that can be used as well for murder as for surgery, and most drugs of value in medicine are harmful and even lethal when used inappropriately.

It is especially ironic that the humane practices of medicine and

This is an expansion of a shorter paper by the author entitled "Cybernetics of Population Control," presented at a seminar in May, 1963, on Human Fertility and Population Problems, held at the American Academy of Arts and Sciences. The original paper was published in March, 1964, in the *Proceedings* of this seminar (Schenkman Publishing Company, Cambridge, Mass.). It was also published in the February, 1964, *Bulletin of the Atomic Scientists*, and we are indebted to both of these publications for their permission to use much of the original text.

public health, dedicated to reducing physical suffering and prolonging healthful lives, should be the primary cause of a major social disease. This disease is the unprecedented increase in the world population, especially in economically underdeveloped countries least able to afford the increased burden. Prior to World War II, during nearly 100 years following Pasteur and the development of bacteriology and immunology, the European population growth rate accelerated as a result of the conquest of infectious diseases and the improvement in public health measures, which reduced death rates. Since World War II western medicine has administered its sophisticated techniques in underdeveloped countries. Medical missionaries, using relatively inexpensive insecticides, antibiotics, inoculations, and vaccinations applied to masses of people, have drastically reduced the death rate, leaving the birth rate, always large, either unchanged or somewhat increased as a result of improvements in health and longevity. This beneficent process has greatly increased populations in the poverty-stricken countries of Asia, the Near East, Africa, and Latin America, which now contain, according to Kingsley Davis, 69 per cent of the world's adults and, through marked decreases in infant mortality, 80 per cent of its children.¹

In most of the underdeveloped countries, the death rate has dropped at a record rate. Davis has pointed out that on the island of Mauritius in the Indian Ocean, within an 8-year period after the war, life expectancy increased from 31 to 51 years, a gain that took Sweden 130 years to achieve. In Taiwan, within two decades, the life expectancy increased from 43 to 63 years. This 20-year gain in life expectancy took 80 years to effectuate in the white population of the United States. These figures are typical of what has happened in most underdeveloped countries. In many countries the population is increasing at the rate of over 3 per cent per year, which will result in a doubling in 23 years. The world population as a whole is increasing at 2 per cent per year, a rate at which it will double in about 35 years. Oncoming generations of poverty-stricken, economically unproductive young people will increase the birth rate further as they come of age. Already this generation in some places is hungrier and more illiterate than that of its parents, and has fewer job opportunities. This is bad news in those countries with rising expectations, which now contain two-thirds of the world's people, such as China, India, Pakistan, the United Arab Republic, and various Latin American countries, where the average per capita income is less than \$100 per year. The increasing numbers of the

unproductive make increasingly difficult the accumulation of developmental capital, since most local produce must be consumed to maintain the growing population.

There are only two solutions to the disease of overpopulation. One is to increase death rates, and the other is to decrease birth rates. So far we have manipulated death control by decreasing death rates and so increasing the population. No one that I know of advocates reversing this process, although a nuclear war would certainly do so, and such a war is made increasingly likely by runaway populations. The alternative solution is birth control and family limitation on a rational basis. Man is the only animal that can deliberately direct and control his own evolution. It will be interesting to see which of these two variables, death or birth, he will manipulate. It must be one or the other, since a 2 per cent growth rate will result in one square yard of land area per person 600 years hence, an obvious absurdity.

We may learn something relevant to our problem from a consideration of how animals regulate and control their population problems. Many organisms possess remarkable methods of population control as contrasted with the conscious devices available to man.

In multiplying cultures of micro-organisms the growth rate accelerates exponentially; but as toxic metabolic products, such as acids or alcohol, accumulate, the rate declines and the curve describing numbers of organisms as a function of time ultimately flattens off. These S-shaped growth curves for bacteria and yeasts have been described by equations aimed at elucidating the dynamics of such population growths. Human populations, when relatively isolated by geography, social habits, and cultural factors, also display S-shaped growth curves; in other words, they reach asymptotic levels as a result of Malthusian brakes such as infectious diseases, war and famine, or, more hopefully, by migration or by rational family planning and birth control. The motivation for family planning has historically been a desire for better economic and educational advantages for small families desirous of upward social mobility. It is this factor that is primarily responsible for the small present growth rates of about a half of one per cent in the most advanced industrial nations of Europe, rather than the Malthusian factors active in more primitive societies.

There are many studies on the regulation of insect populations. It has been shown that the fruit fly, *Drosophila*, above certain pop-

ulation densities decreases its egg laying, and to an amount proportional to the density. Many investigations have been made of flour beetles. Below a fixed number of grams of flour per beetle, cannibalism occurs in some species, egg production drops off, and in one species crowding results in females puncturing and destroying some of the eggs they have produced. Frequency of copulation also declines with crowding. There are some species of flour beetles with glands that produce a gas, the release of which is increased with crowding. This gas is lethal to larvae and acts as an antaphrodisiac at high densities of population. Flour contaminated with beetle excrement inhibits egg production of one species of beetle investigated, and the mixing of this contaminated flour with fresh flour decreases the rate of population growth, which is entirely reversible in the presence of fresh flour. In these cases, the food supply is ample.

Among populations of mammals other than man, it was long thought that food and predators were the controlling factors in limiting populations of hares, lemmings and other rodents as well as of deer, caribou, and other forms. The predators might be lynxes, wolves, foxes, and birds of prey, or micro-organisms producing epidemic diseases. It was thought, for example, that the four-year cycles of build-up and decline of lemming populations terminating in their suicidal migrations were due to an increase in predators accompanying population growth, which ultimately caused the panic and decline. But the migrations and deaths appear now not to be caused by the predators. Rather, the predators appear to multiply in response to the multiplying prey. Similarly, for well over a century various observers have reported repetitive wide cyclic variations in the number of fox and lynx pelts taken by trappers in our northern woods. These predators increase in number following cyclic increases in their prey. Lionesses have been reported to bear larger litters, two to four cubs, in environs of plentiful game. When game is scarce, there are only one or two cubs per litter. While the lemming cycles have not been studied as systematically as those of some other species, it seems likely that these four-year fluctuations in population densities are determined by factors now known to regulate population cycles in other mammalian species, and I should now like to say something about these factors.

In past years the snowshoe hare population of Minnesota has been studied extensively. These populations rise and fall through cycles of several years' duration. There is a period of build-up, followed by a dying off. Why do these marked oscillations in numbers

of hares occur? It was observed that when the animals died off there was usually plenty of food—they had not starved. There were no evidences of an excessive number of predators. Furthermore, the bodies showed no sign that any specific epidemic had killed them. To quote from a 1939 study of the dead animals: "This syndrome was characterized primarily by fatty degeneration and atrophy of the liver with a coincident striking decrease in liver glycogen and a hypoglycemia preceding death. Petechial or ecchmotic brain hemorrhages, and congestion and hemorrhage of the adrenals, thyroid, and kidneys were frequent findings in a smaller number of animals. The hares characteristically died in convulsive seizures with sudden onset, running movements, hindleg extension, retraction of the head and neck, and sudden leaps with clonic seizures upon alighting. Other animals were typically lethargic or comatose."² The adrenals were hypertrophied in some cases and atrophied in others. Signs of liver disease, hypertension, atherosclerosis and adrenal deterioration were typical of what one finds following Hans Selye's acute syndrome resulting from overactivity of the pituitary-adrenal axis.

Since effects of social stress have been found to limit populations of birds and mammals, a brief discussion of its operation is in order. Elsewhere I have defined stress as follows:³ Any external situation threatening the organism may function as a stress. Situations calling for flight or fight, with their concomitant psychological and physiological expressions of fear and anger, are stressful. Especially in man the processes of inhibiting fight or flight may themselves result in stressful anxiety states. Psychological stress may result from the intensification of our instinctual drives and of the control of these drives to meet the demands of society. Such stresses may be chronic and produce far-reaching disturbances of a psychosomatic nature, including neuroses, in susceptible individuals. The balancing of one's needs and satisfaction in terms of learned inhibitions and prohibitions occasions stresses of this sort. The same stress situation may have quite different significance, psychologically, for different organisms in terms of their life histories and past conditionings, and therefore attempts to objectify and standardize such stresses meet with difficulty.

The physiologist has a variety of measures of how stress may disturb the body's regulation of the internal fluid environment of its tissues. The maintenance of constancy in this internal environment of blood and lymph is of great importance for proper functioning of the body. Blood and urinary measurements of certain

endocrine systems brought into play by stress are particularly useful response indices, and have been used extensively in our laboratories as well as elsewhere. The quantitative analyses of adrenalin, secreted primarily by the medulla of the adrenal gland, and noradrenalin, a neurohumor primarily released at certain synapses and nerve endings of the autonomic nervous system, reflect defense responses especially to acute stress. Blood and urine measurements of the steroid hormones from the adrenal cortex and their metabolites have been used more widely than any other indices in recent years in studies of stress responses in mammals, including man. The adrenal cortex is activated by the pituitary adrenocorticotrophic hormone (ACTH), which, in turn, is released in increased amounts by action of the hypothalamus following bodily damage or threats. The adrenocortical hormones have ubiquitous actions on many tissues involved in response to stress and the maintenance of homeostasis.

Hans Selye has developed the concept of the general adaptation syndrome, which he defines as the characteristic emergency reaction or general stress responses of an animal, developing through three stages: (1) the alarm reaction, in which adaptation is attempted; (2) the stage of resistance, in which adaptation is optimal; and (3) the stage of exhaustion, in which adaptation fails. These various phases of the general adaptation syndrome may be studied in terms of the type of changes in constituents of body fluids, especially those involving activity of the adrenal cortex. In animals, the studies may include determinations, before and after stress, of adrenal size, adrenal ascorbic acid, and adrenal cholesterol as indices of adrenocortical function. Selye has concluded that many diseases are primarily a result of failure of the bodily mechanisms for adaptation to meet chronic stress situations adequately. He considers that disturbed patterns of endocrine secretion following the prolonged application of stressors may result in various chronic diseases and he thus speaks of the diseases of adaptation resulting from prolonged stress.⁴

Prolonged stressor actions may produce anxiety and chronic behavioral disturbances in man and in experimental animals. The role of life stresses as contributory agents to hypertension, arthritis, ulcers, skin disorders, asthma, and other allergic manifestations has been investigated by many biochemical, physiological, psychological, and psychiatric procedures. Experimentally induced states in animals, closely resembling the neuroses and psychosomatic disturbances seen in man, have been regularly brought about by frustrating

conditioned reflex techniques, in themselves mild procedures but productive of highly abnormal and crippling behavior when carried on at regular intervals over periods of time. Life stressors producing neurotic behavior in man are very varied and may be difficult to define or to measure. In the biosciences, stresses for the most part are not directly identifiable, but are measured by the strains they produce as reflected in the above indices, especially those reflecting activity of the adrenal cortex.

In studies of rodents it has been found that, after the severe stress of winter crowding in burrows, there was much fighting among the males, sex drives were at a low ebb, the young were often eaten, and the females produced premature births. Susceptibility to non-specific infections was also found, another by-product of excessive production of adrenal corticoids. After the numbers of such a colony are depleted through the effects of the stress syndrome, the colony then tends to build up again, going through repeated cycles of growth and decline.

There are many other examples. About forty years ago, a pair of deer was put on a small island of about 150 acres in Chesapeake Bay. The deer were kept well supplied with food. The colony grew until it reached a density of about one deer per acre. Then the animals began to die off, and this in spite of adequate food and care. When these dead animals were examined, marked evidence was found that the adrenal stress syndrome had been in operation. Studies made of the crowding of animals in the Philadelphia Zoo disclosed that in some species there was a ten-fold increase in atherosclerosis under conditions of severe crowding, as well as many other symptoms characteristic of stress. John Christian of the Naval Medical Research Institute made population studies in relation to the crowding of mice. In his 1950 paper in the *Journal of Mammalogy* entitled "The Adreno-pituitary System and Population Cycles in Mammals," he wrote in part: "We now have a working hypothesis for the die-off terminating a cycle. Exhaustion of the adreno-pituitary systems resulting from increased stresses inherent in a high population, especially in winter, plus the late winter demands of the reproductive system, due to increased light or other factors, precipitates population-wide death with the symptoms of adrenal insufficiency and hypoglycemic convulsions."⁵

John Calhoun at the National Institute of Health has studied effects of crowding on rats, and I should like to describe his work in some detail. He investigated colonies of rats kept in pens at critical

levels of crowding, and under these circumstances observed high infant mortality, high abortion rates, failures of mothers to build nests. The young were often scattered about and eaten. When the rats were examined, there was also evidence of the stress syndrome, and Calhoun has spoken, most appropriately, of what he calls "pathological togetherness." He has reviewed this work in an article entitled "Population Density and Social Pathology," published in the *Scientific American*, in February, 1962.

Calhoun confined wild Norway rats in a one-quarter-acre enclosure with plenty of food and water. At the end of 27 months the population stabilized itself at 150 adults. From the very low adult mortality rate in uncrowded conditions, one would have expected a population of 5000, not 150 rats. But infant mortality was extremely high. The stress from social interaction disrupted maternal behavior so that only a few of the young survived. Calhoun later studied groups of domesticated white rats confined indoors in observation rooms under better controlled conditions. Six different populations were examined. Each group was allowed to increase to twice the number that his earlier experience indicated could occupy the allotted space with only moderate stress. Pathological behavior was most marked in the females: pregnancies were often not full term; there were many abortions and many maternal deaths; the mothers often could not nurse or care for their young. Among the males there was much sexual deviation, homosexual behavior and cannibalism, and abnormal behavior ranging from frenetic overactivity to pathological withdrawal, in which some males emerged from their nests only to eat and drink. Patterns of social behavior were thus badly deranged at twice normal crowding.

The experiments took place in four interconnecting pens, each 6 x 6 feet in area. Each was a complete dwelling unit, with a drinking fountain, a food hopper, and an elevated artificial burrow, which was reached by a winding ramp that held five nest boxes. One of these storied rat apartment houses was located in each of the four pens. There was comfortable space in the colony for 12 adult rats in each pen, the size of group in which rats were normally found to thrive. The setup should thus have been able to support 48 rats comfortably without overcrowding. At the stabilized number of 80 to 100, double the comfortable population, which they were allowed to reach by breeding, an equal distribution of the animals would have found 20 to 25 adults in each pen, but the animals did not dispose themselves in this way.

Biasing factors were introduced in the following fashion. Ramps were arranged enabling the animals to get from one pen to another and so traverse the entire four pens in the room. However, the two end pens, numbers 1 and 4, each had only one ramp connecting them with pens 2 and 3 respectively, while the middle pens had two ramps each, one ramp connecting in each direction. The rats had to make a complete traverse of the pens to go from one of the end pens to the other. This arrangement of ramps immediately weighted the probabilities in favor of a higher density in the two middle pens, since pens 2 and 3 could be reached by two ramps, whereas pens 1 and 4 by only one ramp each. With the passage of time strange aspects of the behavior of the group skewed the distribution in an unexpected way. As a result there developed an unexpected arrangement of the sex ratios of the animals in the various pens. The females distributed themselves about equally in the four pens, but the male population was concentrated almost overwhelmingly in the middle pens, the reason for this being the status struggle which takes place among the males. Shortly after six months of age each male enters into a round robin of fights that eventually fixes his position in the social hierarchy. These fights took place in all of the pens, both the middle and the end pens; but in the end pens, during the period when the social hierarchy was being established, it became possible for a single dominant male to take over the area as his territory.

Calhoun describes how this came about. The subordinate males in all pens adopted the habit of arising early in order to be able to eat and drink in peace. Rats generally eat in the course of their normal wanderings, and the subordinate residents of the end pens, having been defeated by the dominant males there, were likely to feed in one of the middle pens, where they as yet had not had to fight for status. When, after feeding, they wanted to return to their original quarters, they met with difficulty. By this time the dominant male in the end pen would have awakened and would engage the subordinates in fights as they tried to come down the single ramp to the pen. For a while the subordinate would continue his efforts to return to his home pen, but after a succession of defeats he would become so conditioned that he would not even make the attempt. In essence, Calhoun points out that the dominant male established his domination in the end pens and his control over a harem of females, not by driving the other males out, but by preventing their return over the one lead ramp. While the dominant male in an end pen slept a good part of the time, he made his sleeping quarters at

the base of the ramp. He was therefore on perpetual guard, awakening as soon as another male appeared at the head of the ramp. He usually had only to open his eyes for the invader to wheel around and return to the adjoining pen. Since there were two ramps for pens 2 and 3, no one male could thus dominate both means of access. The dominant males in pens 1 or 4 would sleep calmly through all the comings and goings of his harem, seemingly not even hearing them. His behavior during his waking hours reflected his dominant status. He would move about in a casual and deliberate fashion, occasionally inspecting the burrow and nests of his harem. But he rarely entered a burrow, as did some other males in the middle pens merely to ferret out the females. A territorial male might tolerate other males in his domain provided they were phlegmatic and made themselves scarce. Most of the time these subordinate males hid in the burrows with the adult females, and only came out onto the floor to eat and drink; they never tried to engage in sex activity with the females.

In the end pens, where population density was thus kept low, the mortality rate among infants and females was also low. Of the various social environments that developed during the course of the experiments, the breed pens—as the two end pens were called—were the only healthy ones, at least in terms of group survival. The harem females generally made good mothers and protected their pups from harm. In the middle pens the pregnancy rates of the females were the same as those in the end pens, but a very much lower percentage of their pregnancies terminated in live births. In one series of experiments 99 per cent of the young born in pens 2 and 3 perished before weaning, and in others of the six experiments somewhere between 80 and 95 per cent perished.

The females that lived in the densely populated middle pens became progressively less adapted to building adequate nests, and eventually stopped building them at all. Normally rats of both sexes build nests, the females doing so most vigorously around the time of parturition. It is an undertaking that involves repeated periods of sustained activity, with the searching out of appropriate materials, such as strips of paper, and transporting the strips to a nest, which they arrange in cup-like form. In the crowded middle pens, however, the ability of the females to persist in this activity was greatly impaired. The females began merely to pile the strips in heaps, sometimes trampling them into a pad that showed little sign of cup formation. Later they brought fewer and fewer strips to the nesting

site, and in the midst of transporting a bit of material often dropped it and engaged in some other activity occasioned by contact and interaction with other rats met on the way. In the extreme disruption of their behavior during the later months of the population's history, they built no nests at all, but would bear their litters on the sawdust in the burrow box. The females also lost the ability to transport their litters from one place to another, a task they would normally accomplish with skill. If they did try to move a litter, they would drop individuals and scatter them about on the floor. The infants thus abandoned throughout the pens were seldom nursed. They would die where they were dropped and be eaten by the adults. In the middle pens, when a female came into heat, she would be relentlessly pursued by all of the males until she was exhausted, with the result that, within a relatively short time, 25 per cent of the females in the crowded pens died; in contrast, only 15 per cent of the adult males died over the same period in the middle pens. In the end brood pens, however, this sort of thing did not happen. The females there would retire to bear their young in nests they made in a normal fashion, and were protected from the excessive attention of other males by the territorial male.

In the middle pens, a great deal of fighting among the males went on, with now one and now another assuming the dominant position. After a while, most of the males in the middle pens gave up the struggle and simply retired, making themselves as scarce as possible and spending a lot of their time sleeping. In contrast, in pens 1 and 4 one male predominated and peace reigned. These dominant males took care of the females and of the juveniles, never bothering them in any way.

Among the sub-dominant males there was much abnormal behavior. For instance, there was a group of homosexuals. They were really pan-sexual animals, and apparently could not discriminate between sex partners. They made sexual advances indiscriminately to males, juveniles, and females that were not in oestrus. Frequently attacked by their more dominant associates, they very rarely contended for status.

Another type of male emerged in the crowded pens. This was essentially a very passive type, that moved a good deal like a somnambulist, ignoring the other rats of both sexes, and ignored by all of them. Even when the females were in oestrus, these passive animals made no advances to them, and only very rarely did other males approach them for any kind of play. They appeared to be

healthy, attractive and sleek, but they were simply zombies in their conduct as far as the other rats were concerned.

The strangest of all of the abnormal male types described by Calhoun were what he called the probers. These animals, which always lived in the middle pens, took no part at all in the status struggle. Nevertheless, they were the most active of all the males in the experimental population, and persisted in their activities in spite of attacks by the dominant animals. In addition to being hyperactive, the probers were hypersexual, and in time many of them became cannibalistic. They constantly chased females about, entering their nests, having intercourse with them in the nest, a thing that normal rats would never do. These probers conducted their pursuits of oestrus females in a very abnormal manner, abandoning all courtship ritual, which is characteristic of mating rats.

In these experiments by John Calhoun we see the development of serious pathology directly attributable to overcrowding at only twice the number of rats per unit area normally required for a healthy society. It is tempting to draw a comparison of city slums with the crowded middle pens and of prosperous suburbs with the orderly end pens, far-fetched though it may be.

We are, however, justified in asking to what extent the stress syndrome may be a limiting factor in reducing the growth rate of human populations. As far as I know, there are no adequate data on which to base an answer. Studies from a number of laboratories, including our own, have demonstrated that the pituitary adrenal system responds under stress in a way similar to that of other mammals. There is direct evidence that inmates of concentration camps experienced acute forms of the stress syndrome that may have accounted for many deaths. Concentration camps would be more appropriate sources of comparison to highly congested animal populations than city slums, since in crowded cities even the very poor do have some mobility. They can escape from their immediate congestion onto the streets and associate with other members of the population. The high incidence of street gangs and juvenile delinquency is especially characteristic of overcrowded city areas and constitutes a form of social pathology. Several studies have also indicated a higher incidence of schizophrenia and of other psychotic and neurotic behavior in congested urban areas than in more spacious surroundings, but other factors may be involved here. The increased incidence of atherosclerosis and other cardiovascular

pathology associated with urban living and its competitive stresses may also be enhanced by crowding, although direct evidence for this effect of population density is lacking. In underdeveloped countries with high birth rates and recently lowered death rates, resulting in population growth rates of 2 to 4 per cent per year, any possible decrease occasioned by the stress syndrome would be obliterated through the action of medical and public health measures that are enhancing life expectancies and would mask any small reduction in life expectancies resulting from stress.

There is a large literature on the social behavior of animals in relation to population density. Of especial importance is a book by V. C. Wynne-Edwards entitled *Animal Dispersion in Relation to Social Behavior*,⁶ some of whose conclusions I should like to summarize.

In nature, when food supplies are fortuitously removed or fail to materialize, a local overpopulation emergency results; among highly mobile flying animals, such as insects and birds, this can be immediately relieved by emigration. The social hierarchy and code of behavior to which the animal subscribes act as devices to force out whatever surplus of animals exists. The exiles may be condemned to perish, or under other circumstances, they may set up new communities in other localities. In the cold boreal and arctic regions, most of the erupting species are birds. Many birds are adapted to exploit intermittent or undependable crops of food, and are to a large extent nomadic in their search for regions where supplies are temporarily plentiful. Two distinct biological functions appear to be served by emigration. One is that of a safety valve to give immediate relief to overpopulation; the other is a pioneering function to expand and replenish the range of the species as a whole, and provide for gene exchange. Emigration of the safety valve kind is associated with stress and with quickly deteriorating economic conditions (locusts). On the other hand, providing pioneers can be afforded only when conditions are good. In more variable environments, both functions tend to become important and to be exercised on a large scale. The individuals expelled are in either case usually the junior fraction of the hierarchy.

In this connection I am reminded of human colonizing activities—the Greek city states that sent young people off to colonize the Mediterranean area, Italy, Sicily, and Africa, and the lands around the Aegean and the Black Sea. It was the younger sons of British families and the emigrants of Portugal, Spain, and France who estab-

lished colonies in the western hemisphere, thereby relieving population pressures at home. Like many animal colonies, Australia was originally colonized by a group very low in the British pecking order, namely, prisoners. Ireland is an especially interesting case. In 1670 Ireland had a population of approximately a million people. By 1845 this had increased to eight million. The Irish were heavily dependent upon one crop, the potato, which was grown on small plots sufficient to feed a family. Over a period of six years (1848-1854), a blight destroyed the potato crop. Nearly a million persons starved and another million emigrated. Agriculture reforms were introduced, the small plots being consolidated for purposes of diverse crop farming, and ultimogeniture was established. But the population continued to fall, until it is now about four million, only half of what it was before the potato famine. The reasons for this decline were continued emigration, and a social change characterized by very late marriages, or often no marriage at all. The pattern is for the youngest son to maintain the farm, care for his parents, and usually not marry while they are alive. The result is that population growth in Ireland is low despite the influence of the Catholic Church.

To revert to animal societies, Wynne-Edwards points out that the same general social machinery that controls safety valve emigrations is involved in regulating such seasonal redispersions of animals as the annual two-way migrations of birds. Among other investigations of mortality promoted by stress, the white stork has been intensively studied. Nestling mortality is often very heavy under crowded conditions; individual chicks may be deliberately killed and sometimes eaten by one of their parents, usually the father. This is most likely to happen where the parents are beginners or young adults, and presumably of lower status in the pecking hierarchy. The killing off of the young in prolific breeding conditions is characteristic of a great many birds that have been investigated, as well as of many mammals, and is a direct result of social stress. Both the killing of the young and cannibalism are known to occur quite widely in mammals: for instance, in rodents, lions, and also in primitive man. Cases of cannibalism are found in fish, spider crabs, spiders, and fratricide in insect larvae of various types. *In all cases experimentally investigated, the mortality is found to be density dependent and to cease below a certain critical population density.*

Mortality from predation, which has also been examined, ap-

appears to be density dependent to the extent that the prey cooperates by making its surplus members especially vulnerable to predators. As mentioned earlier, the density elements in predation seem to arise first on the side of the prey and not on that of the predators. Because of lowered resistance to infective agents following prolonged stress, disease as a form of predation may effectively reduce excessive population. In this case a surplus of individuals predisposed to injury by their dominant fellows naturally experiences a variable amount of uncontrolled mortality, which tends to fall most heavily on the young, as yet unprotected by acquired immunity from bacterial and viral infections. Social stress can lead to casualties at all ages, both through direct and mortal combat and through stress-induced disease. The victim of severe stress is likely to develop physiological disorders affecting many organs, especially the lymphatic apparatus, and including the spleen and thymus, the nervous system, circulatory, digestive and generative organs, the endocrine glands. As we have seen, the effect of stress is especially notable in the adrenal cortex, which serves an intermediary role between the stressor and the organs responding to adrenal cortical hormones. Social stress is sometimes partly physical, as when the exercise of peck-order rights leads to the infliction of wounds, or the withholding of food and shelter. But, as Wynne-Edwards points out, it may also be largely mental, as in man, who in his more unsophisticated states may die from the conviction that he has been bewitched. Instances are known of birds, mammals, and amphibians similarly dying from non-specific injuries apparently induced by social stress.

And now, what about man? What can we do about the world population explosion? We can, of course, do nothing and wait for the stress syndrome or for some new virus to do its work. We can leave our destruction to some trigger-happy dictator with a suitable stock pile of nuclear weapons, or, finally, we can decide on an optimal population for the world and, by education and such social pressure as tax bonuses for small families, try to see that it is not exceeded.

Psychological prejudice, indifference, and downright hostility are the major blocks to planned population limitation. We know many methods of birth control: coitus interruptus, jellies, douches, diaphragms, condoms, surgical procedures, and "the pill," and ongoing research will give us more and better methods, but none is of value if people refuse its use. Among the very poor and

illiterate, cost and the difficulties of use of contraceptives demand massive government aid, financial, social and educational. Prudery and politics, myth, superstition and tradition have so far rendered birth control ineffective in the very countries most in need of it.

There are certain factors that specifically inhibit human population growth. One of these is a rise in the social, economic, and educational level of the people. Thus birth rates in the United States, with the exception of the postwar baby boom, have, in general, fluctuated inversely with economic conditions. Davis has pointed out that in all of the industrialized countries of Europe economic growth always outpaces population growth, thus repeatedly demonstrating that population pressure on the means of subsistence does not operate to lower populations as has often been thought. Other things being equal, the richer the nation the slower the population growth, an observation sharply divergent from the claim that the population explosion is good for business. The decline in birth rates attendant on opulence results from a desire for upward social mobility on the part of parents, who know that their incomes will go further to advance the welfare of a small family and will make possible a better education for a few children and higher standard of living for themselves than for a big family. Within a single country and at a given time, one can see this principle in operation. Thus, in northern industrial Italy, the birth rate is low compared to that in the poor agricultural regions of the south, and this despite the influence of the Catholic Church and cash bonuses paid by the Italian government to encourage large families.

Decrease in birth rates with opulence has led some to the erroneous conclusion that an increase in food supplies decreases birth rates. It has therefore been argued that all we need to do to control the population explosion is to feed people well, as if there were an inverse correlation between food intake and fertility. As a matter of fact, the opposite appears to be the case. We have already pointed out that predatory animals increase in numbers and may have larger litters in the presence of ample prey. This fact has been established for a number of species, although its basis is obscure. A parallel situation also appears to exist for man. William Langer has presented an interesting and well documented discussion of what he calls "Europe's Initial Population Explosion."⁷ Before the mid-eighteenth century Europe's population increases were slow and spasmodic. He points out that a population of 140 million in 1750 rose to 188 million in 1800 and to 266 million by 1850. A

Careful consideration of death rates demonstrates that they did not decrease significantly over this period. The increase appears to be due to fertility increases, and the question is why?

Langer points out that historically it has been established that there are correlations between harvest conditions and marriage and birth rates. In Sweden, where careful statistics go back to the seventeenth century, the annual excess of births over deaths in the eighteenth century was only 2 per thousand after a poor crop, but 6.5 after an average harvest, and 8.4 after a bumper crop. As late as the mid-nineteenth century high wheat prices resulting from scarcity were reflected in low marriage rates and to some extent in low birth rates.

Langer attributes the European population increase between 1750 and 1850 to the introduction of potato culture. The potato, introduced from South America via Spain in the late sixteenth century, within a hundred years had spread widely over Europe. It furnished a food yield per acre of two to four times that of grain, and an acre of even poor soil could feed a large family. Langer points out that under the feudal system the seigneur frequently denied marriage to able young people he had selected for special service, and guild masters also blocked or delayed marriages of apprentices and artisans. Thus during the seventeenth and early eighteenth centuries marriages were late and few compared to a later period after the old regime had broken down, with a resulting increase in marriages and birth rates.

Potato cultivation contributed to the decline of great feudal estates. It facilitated early marriages and made possible the nourishment of larger families. Thus in Ireland, with no industrial revolution and no war and no change in patterns of famine or disease and despite terrible poverty, the population increased from 3,200,000 in 1754 to 8,174,000 in 1846, just before the potato famine, the disastrous consequences of which we have seen. These figures do not include some 1,500,000 who migrated before the famine.

Thus both human and animal populations tend to increase with increasing food supplies, other things being equal. On the other hand, human populations decrease their growth rates with opulence, for in the opulent society economic and social advantages other than food make for small families and usually constitute more effective agents for reducing birth rates than improved food supplies are in increasing them.

Grenville Clark has argued that the population explosion prob-

ably cannot be controlled until the world has accepted universal and complete disarmament under world law, and devotes a substantial part of the 120 billion dollars now being spent on weaponry to raising the living standards of have-not peoples. He bases his view on the often demonstrated fact that birth control procedures are used extensively only by literate and prosperous people, with hope and ambition for bettering their own lots and those of their children. The take-off point for family planning and limitation requires a critical level of education and prosperity not now found in the very poor countries.

The completely gloomy view would be that if we do not manage to disarm within a decade or two we may solve the population problem by nuclear extermination. In any case, the two major problems of our time—nuclear war and the population explosion—are closely linked together. The physical sciences and the medical sciences have given mankind these two world-wide challenges never dreamed of by previous generations. Only by fundamental changes in our ways of thinking can they be solved.

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Mechanisms of Population Control

H. Hoagland

(Résumé)

Les progrès accomplis dans le domaine de la bactériologie et de l'immunologie ont permis de réduire le taux de la mortalité dans le monde, mais ils sont à l'origine d'un accroissement de la population, notamment dans les pays en voie de développement. Deux façons d'endiguer l'explosion démographique génératrice de famine : accroissement délibéré du taux de la mortalité - piètre solution - , diminution réfléchie du taux de la natalité - contrôle des naissances - .

A titre d'information, il est possible d'étudier la façon dont les animaux résolvent ce problème. Quelle que soit leur place dans la classification, ils sont sujets à des augmentations périodiques de leur natalité, suivie de stabilisation puis de diminution. L'analyse de ces phénomènes met en évidence l'existence d'une "contrainte sociale" dès qu'apparaît un certain taux de population. Cette contrainte, chez les mammifères notamment, peut provoquer des sécrétions hormonales (adrénaline), des états d'anxiété... pouvant entraîner, à plus ou moins longue échéance, des désordres physiologiques. Une expérience sur des rats (publiée en 1962) est très significative : l'augmentation de population entraîne en particulier des déviations nettes dans le comportement des animaux entre-eux.

La régulation des espèces peut s'effectuer de diverses façons : sécrétion de produits toxiques par des cultures de microorganismes, destruction des oeufs, cannibalisme, diminution de la copulation chez les insectes. L'émigration pratiquée chez les oiseaux semble d'ailleurs avoir été une solution adoptée par les hommes au moment de la conquête coloniale.

Quelle solution faut-il adopter en ce qui concerne l'espèce humaine ? Attendre ou bien agir par l'éducation. La seule solution valable serait de consacrer une importante partie des sommes actuellement utilisées pour l'armement à l'éducation des peuples, à l'élévation de leur niveau de vie, sinon l'extermination nucléaire pourrait bien devenir d'ici quelques dix ou vingt ans l'ultime solution du problème de la surpopulation.

Mecanismos de regulación de la población

H. Hoagland

(Resumen)

Los progresos realizados en la esfera de la bacteriología y de la inmunología han permitido reducir la tasa de mortalidad en el mundo, pero han producido un crecimiento de la población, especialmente en los países en vías de desarrollo. Hay dos maneras de contener la expansión demográfica generadora de hambre : aumento deliberado de la tasa de mortalidad (solución inadmisible) o disminución reflexiva de la tasa de natalidad (regulación de los nacimientos).

A título de información se puede estudiar de qué manera resuelven los animales ese problema. Cualquiera que sea el lugar que ocupen en la clasificación taxonómica, las especies animales están sujetas a aumentos periódicos de su natalidad, seguidos de estabilización y luego de disminución. El análisis de esos fenómenos revela la existencia de una "coerción social" en cuanto se alcanza un cierto nivel de población. Esta coerción, particularmente en los mamíferos, puede provocar secreciones hormonales (adrenalina), estados de ansiedad, etc., capaces de producir, en un plazo mas o menos largo, trastornos fisiológicos. Un experimento con ratas (publicado en 1962) ha dado resultados muy significativos : el aumento de la población provoca en particular claras desviaciones en el comportamiento mutuo de los animales.

La regulación de las especies puede hacerse de diversas maneras : secreción de productos tóxicos en los cultivos de microorganismos, destrucción de los huevos, canibalismo y disminución de la copulación en los insectos. La emigración practicada por las aves parece haber sido adoptada por los hombres en la época de la conquista colonial.

¿Qué solución conviene adoptar en el caso de la especie humana ? Esperar o dejar que actúe la educación. La única solución viable sería consagrar una parte importante de las sumas invertidas actualmente en armamento a la educación de los pueblos y a la elevación de su nivel de vida antes de que el exterminio nuclear pueda ser en diez o veinte años la solución final del problema de la superpoblación.

QU'EST-CE QUE LA CYBERNETIQUE ?

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GENESE DE LA NOTION DE CYBERNETIQUE

Le mot "cybernétique", que le profane connaît pour l'avoir lu dans des articles de vulgarisation, évoque en lui trois images différentes dont les rapports internes offrent sans doute le meilleur moyen de cerner l'essence philosophique de cette notion.

La première image évoquée est en général celle de l'association de différentes sciences qui ont découvert des analogies dans les lois qui régissent leurs champs d'investigation respectifs. On pense alors en particulier à la biologie en tant que théorie des êtres vivants et à l'informatique en tant que théorie des systèmes de traitement de l'information que l'homme de la rue appelle "cerveaux électroniques", le spécialiste, "ordinateurs", et tel philosophe "machine à penser", mais qu'il conviendrait, pour être plus précis et éviter l'ambiguïté, d'appeler "machines automatiques pour le traitement des données" ou, plus brièvement, "transformateurs de signaux".

La deuxième image, qui se dégage aussi de nombreux ouvrages de référence, est celle d'une théorie mathématique des processus de régulation, l'exemple classique étant le réglage de la température par thermostat.

Enfin, l'helléniste constatera en outre que ce mot vient du grec [Kubernetes] qui désignait celui qui exerçait, sur un navire, les fonctions - à l'origine confondues - de timonier et de pilote et parfois, dans un sens figuré, celui qui dirigeait un groupe d'hommes ou une communauté /4, 5/.

Aucune de ces images ne traduit exactement le sens du mot "cybernétique" qui commence à se cristalliser, mais aucune n'est entièrement fausse.

Ampère fut probablement le premier à appliquer le terme "cybernétique" à une science. Dans son "Essai sur la philosophie des sciences" (1834) il nomma ainsi la science des modes d'action possibles d'un gouvernement. Ces modes d'action sont évidemment des méthodes "finalisées" : elles tendent vers un but politique. Celui-ci doit être fixé auparavant. La détermination des buts est étrangère à la cybernétique ; elle ne constitue d'ailleurs pas une activité scientifique. L'appellation donnée par Ampère est suggestive : le pilote "gouverne" le navire ; il connaît les modes d'action permettant d'atteindre le but fixé par le capitaine.

CONTENU DE LA NOTION DE CYBERNETIQUE

Ces quelques remarques, d'ordre surtout historique, auront donné une idée approximative de ce qu'est la cybernétique ; il n'en existe pas encore de définition précise et généralement admise. Cependant, nous pouvons maintenant savoir sans trop de difficulté l'acception - suffisamment générale et pourtant assez précise - de la cybernétique qui semble s'affirmer actuellement, du moins dans les pays d'expression allemande /12/. Pour cela nous allons partir de l'analyse des fonctions essentielles du pilote et du timonnier, c'est-à-dire des personnages dont l'équivalent approximatif était autrefois désigné par le mot [Kubernetes]. Certes il est rare que le contenu sémantique d'un mot reste défini longtemps de façon précise et inchangée, et les faits qu'il s'agit de désigner évoluent aussi. Par conséquent, comme le montre une intéressante étude philologique de Joh's-E. Heyde /10/, le retour aux sources du mot "cybernétique" ne peut servir qu'à une première approximation et ne saurait aucunement remplacer l'étude de la réalité.

Sur un navire (de même que dans tout autre "système sociotechnique") on peut distinguer quatre instances (fig. 1) :

1. Le capitaine, qui fixe le but à atteindre et qui, pour cela, doit être apte à choisir entre différents buts possibles, autrement dit à prendre des "décisions primordiales" ;
2. Le pilote, qui détermine la situation actuelle (POSITION) et conçoit un programme d'action en vue de l'amener en coïncidence avec la situation désirée (BUT). Pour cela, il doit pouvoir garder en mémoire la valeur correspondant au but, mesurer celle qui correspond à la position actuelle, comparer ces deux valeurs et transmettre au timonnier le "programme" qui résulte de cette comparaison, sous forme d'ordres successifs que l'on peut appeler décisions "secondaires", "déduites" ou "déterminées" ;
3. Le timonnier, qui agit sur les commandes dans le sens indiqué par le pilote et ainsi, sans gros effort personnel, met en oeuvre la grande énergie du système de propulsion de façon à exécuter les décisions du pilote ;
4. Le système de propulsion (dans le cas le plus simple, les rames) qui fournit le travail physique permettant d'effectuer la modification de situation désirée.

Il existe un rapport entre une décision du pilote, la modification de situation qu'elle entraîne et la décision suivante que le pilote déduira de la situation ainsi modifiée (c'est la "rétroaction" ou action en retour sur la cause). Hermann Schmidt qualifie ce rapport de "relation circulaire".

L'exemple illustré par la figure 2 montre que les quatre "instances cybernétiques" caractérisent les activités les plus diverses de l'homme, de sorte que les concepts fonctionnels de "capitaine", "pilote", "timonnier" et "rameurs" peuvent être employés dans un sens général en cybernétique. Cette figure montre aussi quelles fonctions il est possible de transmettre à des machines : la fonction de rameur peut être assignée à une machine dite "traditionnelle" dans notre exemple, à une moto-pompe, et les fonctions du pilote et de timonnier, à un appareil cybernétique, en l'occurrence un régulateur de niveau d'eau. D'une manière générale, la technique cybernétique se distingue de la technique traditionnelle par le fait qu'elle crée des mécanismes qui, au lieu d'assumer la fonction de "rameur", exercent celles de "pilote" et de "timonnier", autrement dit de [Kubernetes], ce terme acquérant désormais le sens, un peu plus abstrait, d'organe assurant le traitement ou la coordination des informations.

La technique ne se limite pas aux constructions mécaniques ; elle inclut toute utilisation systématique de moyens disponibles en vue d'atteindre des objectifs prédéterminés. Si les moyens dont on dispose sont d'ordre physique, on parle de technique mécanique, s'il s'agit d'être vivants, ce sera la biotechnique et, dans le cas de groupes humains, la sociotechnique /6/. Un système utilisant des galériens (production d'énergie !) est un produit de la sociotechnique traditionnelle, la gestion d'une entreprise industrielle (production d'informations) relève de la sociotechnique cybernétique. L'utilisation d'un cheval de trait est l'exemple le plus simple de la biotechnique traditionnelle, celle d'un chien de chasse relève de la biotechnique cybernétique. La détermination des objectifs est une condition préalable de l'application des techniques tant traditionnelles que cybernétiques, mais elle n'entre pas dans le cadre de ces techniques.

L'utilisation systématique des moyens disponibles n'est pas vraiment possible sans une base scientifique. Aux trois domaines de la technique cybernétique, à savoir la technique mécanique, la biotechnique et la sociotechnique, correspondent par conséquent trois disciplines scientifiques : la cybernétique de l'ingénieur, la bio-cybernétique et l'informatique, c'est-à-dire la théorie des mécanismes d'information qui peuvent être qualifiés, suivant le cas, de physiques, de biologiques ou de psychologiques, et qui enregistrent des "messages", les traitent et les transmettent dans le temps et dans l'espace. On reconnaît une analogie de structure entre ces mécanismes si l'on fait abstraction de leurs particularités contingentes d'ordre physique, physiologique ou psychique, c'est-à-dire si l'on perçoit, par exemple dans les figures 3a et 3b, deux manifestations différentes de la même notion abstraite *κυβερνητής* (pilote et timonnier !). Nous appelons cybernétique "générale" ou "formelle" la théorie des systèmes d'information abstraits. Ses résultats peuvent trouver une application concrète dans les trois disciplines déjà citées que nous appellerons maintenant cybernétiques "sectorielles" ou "matérielles" (figure 4).

Cela nous conduit à poser la définition suivante :

La cybernétique est la théorie des possibilités fonctionnelles des systèmes d'information, abstraction faite de leurs particularités physiques, physiologiques ou psychologiques ; c'est ensuite l'application de cette théorie abstraite à des systèmes pré-existants d'ordre physique, physiologique ou psychologique et enfin la réalisation méthodique de systèmes de ce genre en vue d'atteindre des buts fixés à l'avance.

Nous avons dit que par "système d'information", nous entendons un système qui reçoit des messages ou les transmet soit dans l'espace, (téléscripteur), soit dans le temps, (mémoire à bande magnétique). La cybernétique aura donc pour base une théorie générale de l'information. Avant d'étudier le système lui-même, elle explique les concepts de message, de signal et de signe (théorie des signes), analyse les structures possibles du message (théorie du codage) et en détermine le contenu (théorie de l'information).

Le niveau suivant est celui de la théorie générale des systèmes d'information (théorie générale du traitement des données). Elle étudie, dans le cas le plus simple ("théorie des coordinations"), comment les messages émis par un système (par exemple "24") se coordonnent avec ceux que ce système a reçu précédemment (par exemple " $3.8 = ?$ "). Dans des cas plus complexes (par exemple " $3.867 = ?$ ") elle étudie, en tant que "théorie des automates abstraits" ou "théorie des systèmes dynamiques abstraits", la suite (ou encore l'évolution continue) des états du système résultant des données reçues, ou bien les états intermédiaires entre l'entrée et la sortie des messages. A ce niveau, il faut déjà souvent tenir compte de "relations circulaires" à l'intérieur du système.

Au troisième niveau de la cybernétique générale se situe la théorie générale des "relations circulaires". Celle-ci élargit le champ d'observation à l'environnement du système d'information, (environnement dont provient l'information enregistrée (position ou valeur actuelle) et qui est modifié par des (ré-)actions, autrement dit par les messages émis par le système, ce qui influe sur les observations ultérieures. Les "systèmes d'adaptation", qui tendent à un état final stable (valeur visée) constituent le principal type de système à "relations circulaires" extérieurs. Ils se répartissent en deux classes : d'une part, les systèmes de régulation comme ceux qui sont illustrés par les figures 2 et 3 ; d'autre part les systèmes d'apprentissage par adaptation (exemple : un rat qui apprend à sortir d'un labyrinthe, après un certain nombre d'essais et d'erreurs).

Au quatrième niveau de la cybernétique, le plus complexe, la fonction de pilote apparaît aussi dans l'environnement du système ; il s'agit alors d'étudier le fonctionnement de différents systèmes d'information qui agissent en opposition ou en coordination. C'est le cas de la théorie générale des jeux stratégiques, de la planification de la coopération informationnelle (cybernétique d'organisation), de la pédagogie cybernétique et de la cybernétique d'Ampère. On pourrait appeler le quatrième niveau "Théorie des complexes de systèmes" ou "oligologie".

Aux quatre stades de la cybernétique générale (figure 5) correspondent de nouveau des applications aux cybernétiques sectorielles, de sorte que l'on est amené à projeter la figure 4 dans l'espace en y introduisant quatre "niveaux" superposés suivant le "schéma" de la figure 5.

MESSAGE ET INFORMATION

Le "pilote" prend connaissance de la situation actuelle au moyen de signaux, par exemple les indications d'un appareil de mesure. Les signaux sont des faits matériels qui permettent de conclure à l'existence d'autres faits /16/. Ce raisonnement est d'abord un phénomène qui, pour l'informatique, se déroule au niveau de la conscience du pilote. Par suite, les signaux sont pour lui des supports de signes /2/ indiquant la température, la direction suivie, le niveau d'eau, la vitesse, etc. Les signes l'informent donc sur l'environnement (et, par ailleurs, sur les buts fixés par le capitaine). Les notions de signal (=support de signe) et de signe sont regroupées sous le terme plus général de "message".

Extérieurement, rien ne permet évidemment de déterminer si le pilote perçoit dans les signaux l'indice de quelque chose qui s'y trouve exprimé, et dont il tire des conclusions (traitement de l'information) ou bien si les signaux ne font que déclencher une suite de réactions de cause à effet, comme la pression exercée sur un bouton d'ascenseur. On peut donc considérer que la fonction des machines cybernétiques et des systèmes biocybernétiques présente une analogie avec les phénomènes conscients et dire que ces machines ou ces systèmes fonctionnent "comme si" ils recevaient des signes, en tiraient des conclusions et transmettaient d'autres signes. Comme, en fait, seule la structure de la fonction apparente importe, on parle dans ce cas également de réception, de traitement et de transmission d'informations. Afin d'éviter toute erreur d'interprétation sur ce qu'est la cybernétique, il est indispensable de bien comprendre que si l'on considère ces fonctions "comme si" elles s'exerçaient consciemment, c'est uniquement pour des raisons heuristiques¹⁾, de même que, dans le secteur des sciences humaines, où exceptionnellement les processus conscients ne relèvent pas du "comme si", l'on tend inversement, mais c'est encore pour des raisons heuristiques (afin de prendre un recul suffisant, à élaborer des modèles relevant de la cybernétique de l'ingénieur.

Comme nous l'avons vu, un signe indique quelque chose d'autre. Ce quelque chose peut être la cause (source) du signe ; ainsi, un biface trouvé dans une grotte est "signe de" peuplement paléolithique. Mais ce quelque chose peut aussi être cela même qui est désigné par le signe (le sens) : le mot "arbre" est le "signe" qui correspond à l'arbre. Faire correspondre des signes à des sens, c'est coder ces sens par les signes. On peut coder un sens - il peut s'agir par exemple, d'un arbre - à l'aide

1) c'est-à-dire pour faciliter la compréhension et la découverte de nouveaux principes de recherche.

d'un seul signe (c'est le procédé qu'utilise la langue chinoise) ou par une série de signes (notre écriture alphabétique en est un exemple). Cette dernière solution présente l'avantage d'exiger moins de signes différents (en français 26 majuscules et autant de minuscules). Cependant, elle présente un inconvénient : la série de signes nécessaires au codage d'un sens est d'autant plus longue que l'on dispose de moins de signes.

Le plus petit répertoire de signes différents n'en comporte que deux, par exemple 0 et 1, ou bien impulsion électrique et absence d'impulsion. Supposons que l'on veuille coder la suite des voyelles

/1/ AEAIOEAA

par une série de signes 0 et 1 (c'est-à-dire dans un système "binaire"), on pourra choisir le code A : 00 ; E : 01 ; I : 10 ; O : 11, ce qui donnera :

/2/ 0001001011010000,

soit une série de 16 "signes binaires" ou "bits" (contraction de l'anglais binary digits, "chiffres binaires"). Ce code permet de se passer des "intervalles", qui constitueraient d'ailleurs un troisième signe !

On peut imaginer un autre code, tel que A : 0 ; E : 10 ; I : 110 ; O : 111. On obtient alors :

/3/ 01001101111000

La suite des voyelles est ici codée à l'aide de 14 "bits" seulement, ce qui représente le codage le plus court (le plus "économique") de ce type que l'on puisse proposer pour notre exemple²⁾.

On voit que l'avantage du deuxième code tient au fait que la voyelle la plus fréquente, A, qui forme la moitié des signes de la suite (fréquence $f = 1/2$), n'est codée que par 1 bit, tandis que I et O ($f = 1/8$) sont codés par 3 bits. La longueur de la suite binaire la plus courte permet de coder une suite de signes est appelée son information en bits. Notre suite de voyelles a 14 bits d'information car il faut au moins 14 bits pour la coder. De même, on peut définir l'information d'un signe particulier de la suite. Ainsi la voyelle A, la plus fréquente (probable)³⁾, a ici une information de 1 bit, car elle est codée par 1 bit ("0") dans le code le plus économique pour la suite considérée de voyelles, tandis que le I, plus rare (peu probable), est codé ici par 3 bits ("111") et a donc une information de 3 bits. Nous voyons que l'information d'un signe particulier S_i (dans notre exemple, celle d'une voyelle) est inversement proportionnelle à sa probabilité $p_i \approx f_i$. L'information d'un signe est donc une mesure de son improbabilité, la relation exacte étant :

$$\text{Inf}(S_i) = \log_2 \frac{1}{p_i} \quad 4)$$

²⁾ Il est facile de voir que l'on ne peut réduire davantage la longueur totale de la transcription codée : si l'on codait I simplement par 1 et non par 110, on obtiendrait une séquence 10111 qui pourrait signifier aussi bien EO que IA0, ou encore EIII !

On vérifiera facilement l'exactitude de cette relation fondamentale à l'aide du schéma suivant qui résume notre exemple :

Réserve de signes (répertoire) S :	A	E	O	U
Répartition de la probabilité :	1/2	1/4	1/8	1/8
Valeur de l'information en bits :	1	2	3	3

L'information moyenne (autrement dit la valeur de "l'espérance mathématique" de l'information) est dans notre cas :

$$F(S) = p_1 \cdot \text{Inf}(S_1) + p_2 \cdot \text{Inf}(S_2) + p_3 \cdot \text{Inf}(S_3) + p_4 \cdot \text{Inf}(S_4) = 1/2 \cdot 1 \text{ bit} + 1/4 \cdot 2 \text{ bits} + 1/8 \cdot 3 \text{ bits} + 1/8 \cdot 3 \text{ bits} = 1,75 \text{ bit}.$$

$F(S)$ est l'expression de l'incertitude relative au signe du répertoire S qui va suivre. Si tous les signes de ce répertoire peuvent apparaître avec la même probabilité, l'incertitude $F(S)$ prend une valeur maximale, soit dans notre cas :

$$F_{\max}(S) = 2 \text{ bits}$$

Il est possible de coder à nouveau la transcription codée d'une suite de signes en utilisant par exemple les signes d'origine. Posons les correspondances 00:a ; 01:e ; 10:i ; 11:o, la relation /3/ nous donne la suite :

/4/ eaoeioia

En reprenant successivement tous les codes à l'envers, nous pouvons remonter de /4/ à /1/ en passant par /3/. Nous aurions pu, évidemment, utiliser des majuscules dans /4/. Si nous le faisons, nous nous apercevrons que ce qui était exprimé à l'aide de 8 lettres dans /1/ peut l'être par 7 lettres dans /4/ ! La suite de signes /1/ est donc "redondante" ou surabondante, et sa redondance relative est de 1/8, car elle aurait pu être raccourcie de cette valeur, sans perte d'information, grâce

3) On peut admettre que la probabilité p_i d'un signe S_i correspond d'autant mieux à sa fréquence f_i que la suite de signes est plus longue. Si l'on ne jette une pièce que 10 fois en l'air, on peut très bien obtenir "face" avec une fréquence de 0,6, bien que sa probabilité soit seulement de 0,5.

4) $\log_2 x$ est le logarithme de x dans la base 2. Si x est l'inverse $1/p_i$ de la probabilité p_i d'un signe S_i , $\log_2 x$ est par définition sa teneur en information exprimée en bits. Dans un système de 32 bits ayant chacun la même probabilité, celle-ci sera de $1/32$ et l'improbabilité sera donc $x = 32$; par suite, chaque signe aura une information de $\log_2 32 = 5$ bits.

à un codage approprié. La théorie mathématique de l'information démontre que l'on peut calculer la redondance à l'aide de la formule :

$$r = \frac{F_{\max}(S) - F(S)}{F_{\max}(S)}$$

ce qu'il est facile de prouver dans le cas de notre exemple. La redondance, c'est-à-dire la possibilité d'une représentation plus courte, peut bien sûr être due à des causes plus manifestes que la fréquence variable des objets qu'il s'agit de décrire (de coder). En effet une partie d'un message (par exemple du message "3.4 = 12") peut être reconstituée à partir du reste (par exemple, à partir de ".4 = 12"). Cependant, on peut démontrer, même dans ce cas, que la redondance est due à une répartition inégale des probabilités : dans ".4 = 12" il est bien plus probable que c'est un 3 qui manque que n'importe quel autre chiffre !

SYSTEMES CAPABLES D'APPRENDRE

Actuellement, l'étude des processus d'apprentissage dans le cadre de la cybernétique formelle constitue, avec celle des processus de régulation, l'objet principal de la recherche cybernétique. Dans les deux cas on constate des "relations circulaires" au sens de H. Schmidt ; cependant, dans le cas des processus d'apprentissage, il n'est pas possible, contrairement à ce qui se fait pour les processus de régulation, de représenter la différence entre POSITION ACTUELLE et BUT par une grandeur scalaire continue qu'il s'agirait d'amener à zéro (c'est-à-dire une valeur numérique et l'indication d'une unité de mesure, par exemple "-20 cm" dans le cas de la figure 2).

Nous allons tenter maintenant d'éclairer l'approche cybernétique du processus d'apprentissage par une classification⁵⁾ pour laquelle l'apparition de "relations circulaires" ne constitue pas encore un critère de différenciation, et qui ne s'appuie par conséquent que sur les deux premiers niveaux de la cybernétique, tels qu'ils sont définis à la figure 5. La distinction que l'on peut établir entre conditionnement classique, conditionnement instrumental et apprentissage par compréhension se rapporte déjà aux second et troisième niveaux ; la théorie des machines à enseigner se fonde même sur une classification qui présuppose le passage du troisième niveau à celui de la théorie des complexes de systèmes.

Pour la classification qui nous intéresse, la plus simple, on peut poser la définition suivante : un système apprend quelque chose sur son environnement lorsqu'il réduit l'"information subjective" jusqu'à inconscience que celui-ci contient ; on entend ici par "subjectif" le fait que l'information est calculée à partir des probabilités p_i des détails de l'environnement.

⁵⁾ Cette classification, entreprise initialement pour l'esthétique informationnelle /7/, joue aussi un rôle à présent en pédagogie, dans la mesure où celle-ci se fonde sur la théorie de l'information appliquée à la psychologie.

ronnement, présumées "subjectivement" par le système, grâce à la formule déjà indiquée $\text{Inf.}(S_i) = \log_2 1/p_i$.

"Apprendre" consiste alors, dans le cas le plus simple, à "apprendre par coeur", c'est-à-dire, pour la machine, à mettre des informations en mémoire. La quantité totale d'informations inconnues jusque là diminue ainsi de la valeur de l'information mise en mémoire.

A un niveau plus élevé, "apprendre" consiste surtout à utiliser, pour des observations ultérieures, l'information déjà acquise. Cette conception aussi s'applique, non seulement à l'homme et aux animaux, mais aux machines capables d'apprendre. Dans les deux cas apprendre consiste à découvrir et à utiliser les redondances observées précédemment dans le milieu extérieur /11/. Cela ne surprendra pas si l'on songe à l'exemple suivant. Chaque fois que l'on découvrirait un nouvel élément chimique dont on déterminait ensuite la masse atomique, chacune de ses autres propriétés paraissait surprenante (elle contenait une information) jusqu'au jour où l'on découvrait la "redondance" sous la forme du système de classification périodique des éléments. En effet, celui-ci permet de déduire toutes les propriétés du nouvel élément de sa masse atomique (par comparaison avec la masse atomique d'éléments déjà connus, c'est-à-dire en déterminant son numéro atomique). La classification périodique est un exemple qui montre bien comment un regroupement de divers signes (éléments) du répertoire d'origine en classes (métaux alcalins, halogènes, gaz rares etc.) permet d'établir un répertoire de supersignes ayant une plus faible valeur d'information. Nous dirons qu'apprendre ainsi c'est accomplir "un dépassement par formation de classes".

En l'absence de redondance, il n'est pas possible de réduire l'apport d'information autrement que par la formation arbitraire de classes ; par conséquent, il faut apprendre par coeur. En effet, il n'est possible ni de rendre plus rapide, à l'aide d'un meilleur codage, l'interprétation de ce qui est perçu par le système nerveux, ni de recourir à une loi qui permette, à partir d'informations partielles, d'inférer le reste, autrement dit d'économiser des observations. Au contraire, là où l'on se trouve en présence d'une redondance de presque cent pour cent, comme par exemple, dans le cas de la marée, l'expérience devient à peu près inutile, tout pouvant être déduit des lois apprises ; dans notre exemple, il est inutile d'observer la marée, puisque la connaissance de sa période permet de calculer à l'avance l'heure de la haute mer ou de la basse mer. Il est évidemment plus ou moins facile de reconnaître ces lois, suivant la nature des signes dans lesquels le système récepteur (homme ou machine) décompose les messages : on peut considérer qu'un texte est composé de points blancs et de points noirs disposés sur une grille très fine (éléments des perceptions), de lettres ("supersignes" du 1er degré) ou de mots ("supersignes" du 2e degré). En général, l'information subjective de l'ensemble du texte diminue d'autant plus que le répertoire de signes choisi occupe une position plus élevée dans cette hiérarchie. Nous appellerons "dépassement par formation de complexes" ce passage aux "supersignes" qui sont créés par juxtaposition de signes élémentaires. Il arrive, exceptionnellement, que ce dépassement soit défavorable si l'on examine le texte.

ELU PAR CETTE CRAPULE

On verra qu'il est redondant à 50 %, car après le premier t de "cette" toutes les lettres sont reprises dans l'ordre inverse. On reconnaîtra bien sûr cette redondance plus facilement si, d'emblée, on considère le texte comme un ensemble de lettres. En s'attachant surtout aux mots ou au type d'écriture, on ne reconnaîtrait la loi que beaucoup plus tard.

Ces considérations nous conduisent à penser qu'une machine universelle apprend plus difficilement qu'une machine destinée à un domaine de connaissances précis, et qui ne peut donc analyser un message complexe que selon un petit nombre de modalités. Ce "spécialiste" sera naturellement inutilisable hors de son champ d'action spécifique, et l'on est tenté de transposer de la machine à l'homme.

Lorsque nous avons déterminé l'information moyenne $F(S)$, nous avons supposé que non seulement le répertoire S , c'est-à-dire la liste complète des signes possibles s_i , mais aussi la répartition de la probabilité de ces signes, étaient connus. Dans la pratique, cependant, on parle le plus souvent déjà des objets à coder par les signes (autrement dit : on en code déjà une partie) avant même d'avoir pu en dresser une statistique exhaustive. La statistique provisoire et le code provisoire qui en dérive (ou, en termes plus abstraits : la suite des valeurs d'information correspondantes) doivent pouvoir être améliorés au cours d'une série d'observations ultérieures : c'est là un problème essentiel de la théorie de l'information appliquée à la psychologie, mais ce problème joue aussi un rôle dans la théorie des machines capables d'apprendre /9/. Si, par exemple, on a retiré 10 fois une bille rouge et 15 fois une bille noire d'un sac (dont on pouvait penser initialement qu'il contenait autant de billes de chaque couleur), l'hypothèse selon laquelle la bille suivante sera noire est plus probable que l'hypothèse inverse. Se fondant sur l'expérience acquise, on rejettera la répartition statistique initialement présumée égale, et l'on supposera à présent que le sac contient plus de billes noires que de rouges. On peut démontrer que cet "apprentissage par probabilités" diminue en moyenne l'information subjective, processus que nous appellerons "accommodation informationnelle" et qui constitue, parallèlement au "dépassement", une deuxième forme d'apprentissage de niveau supérieur.

Ainsi la connaissance par coeur, le dépassement, et l'accommodation informationnelle, sont les trois manières qui permettent à un système d'acquérir des informations sur le milieu extérieur, c'est-à-dire /16/ d'adapter un "modèle intérieur du milieu extérieur" (sur lequel la machine ou l'homme mesure avant d'agir les chances de réussite de son action) à ce milieu extérieur, susceptible de changement. Cette conception de l'apprentissage peut être, du moins partiellement et pour ses formes supérieures, représentée quantitativement : apprendre c'est réaliser une économie dans le codage (et par suite dans la mémorisation) des connaissances relatives au milieu extérieur.

Légendes des figures

Fig. 1 : Schéma des instances cybernétiques et des quatre types d'activité humaine.

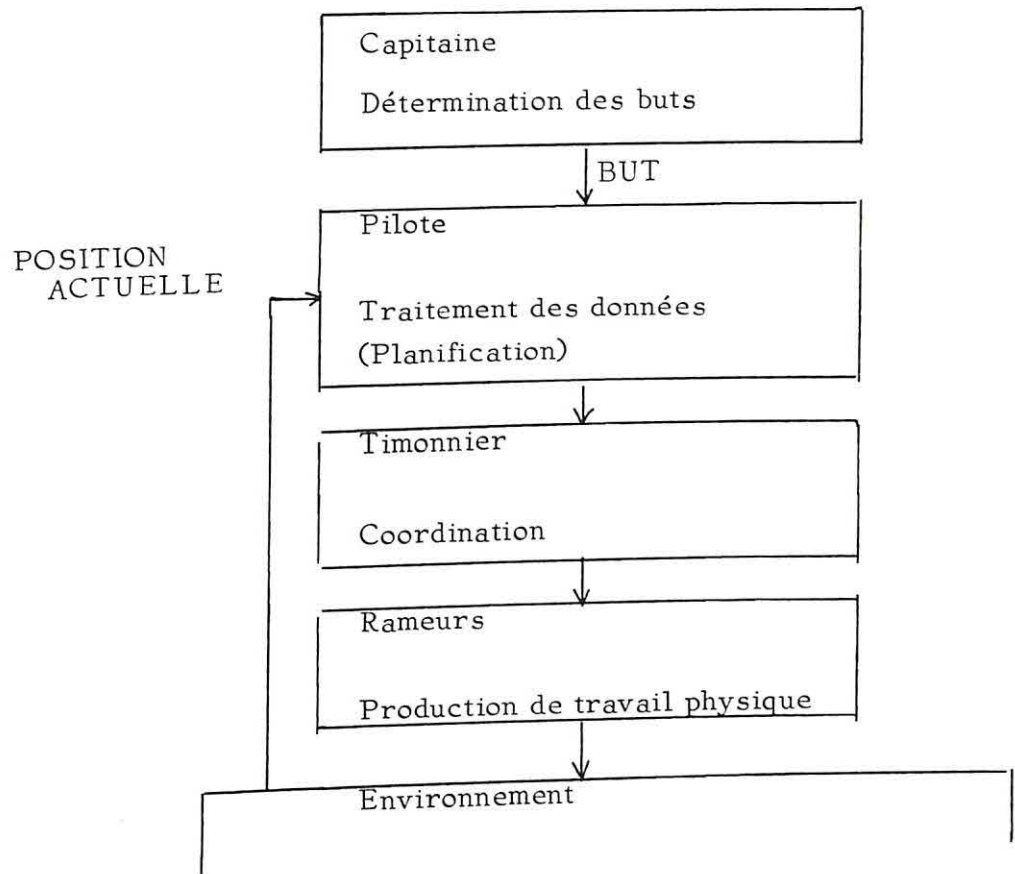


Fig. 2 : Régulation du niveau dans un bassin à écoulement d'eau à une valeur fixée par le capitaine (BUT)

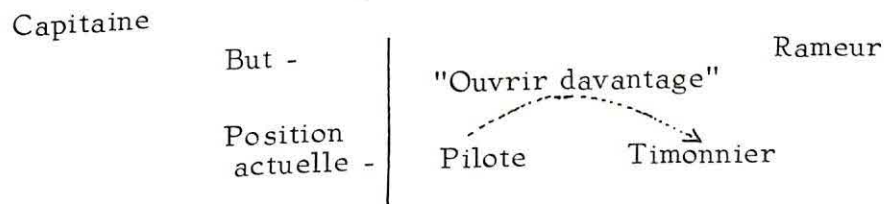


Fig. 3 : Le régulateur à boules (b) est l'un des premiers mécanismes de régulation technique dont la fonction objective celle du κυβερνητης (a) extrait de /1/ .

1 000 ch 1 000 ch

Fig. 4 : Subdivision de la cybernétique en disciplines scientifiques et techniques contigües

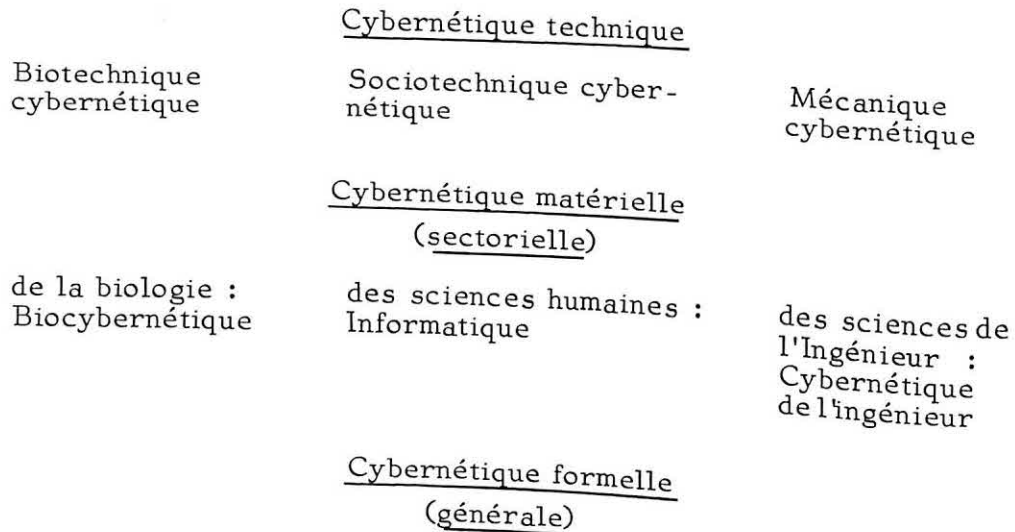
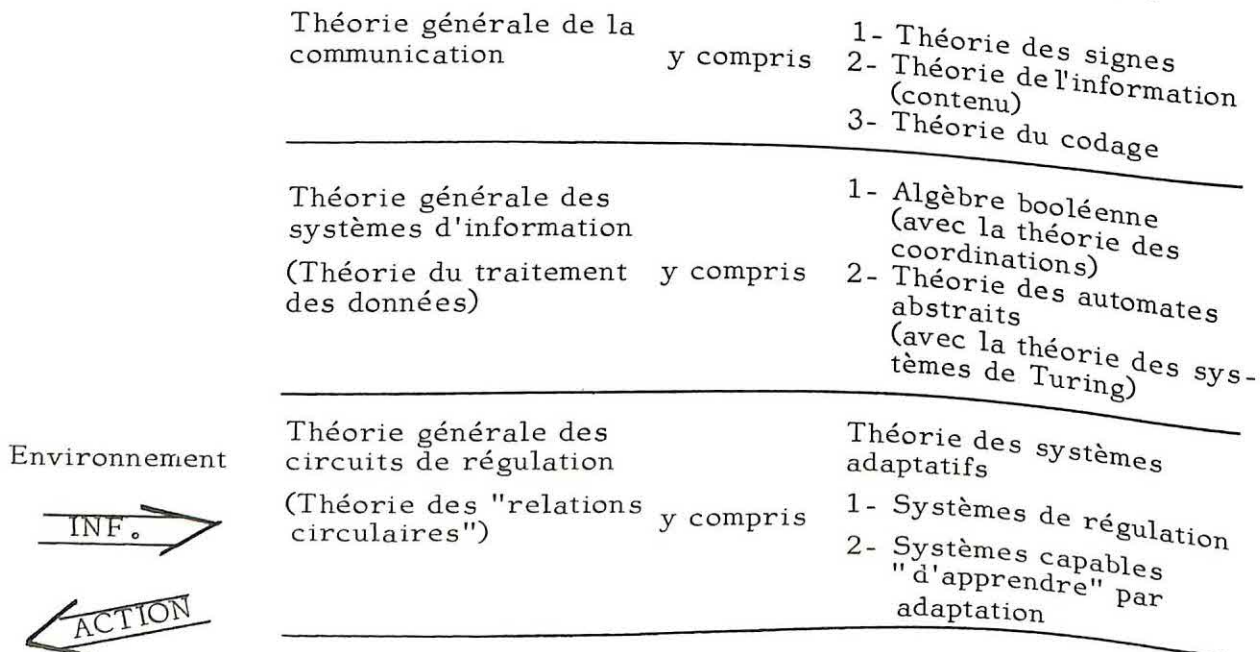


Fig. 5 : Subdivision de la cybernétique générale en quatre niveaux



Environnement	Théorie générale des complexes de systèmes (Oligologie)	y compris	1- Théorie du jeu 2- Cybernétique d'or- ganisation 3- Pédagogie cyberné- tique 4- Cybernétique d'Ampère
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¿Qué es la cibernética ?

H. Frank

(Resumen)

Un análisis histórico del problema lleva al autor a definir la cibernética como la teoría de las posibilidades funcionales de los sistemas de información, la aplicación de esa teoría a sistemas pre-existentes y la realización metódica de tales sistemas para alcanzar determinados objetivos. Por lo tanto, la cibernética se apoya en la teoría general de la información, en la de los sistemas de información (teoría del tratamiento de datos), en la de las relaciones con el exterior (adaptación y regulación) y en la de los sistemas complejos que resumen ese conjunto.

El artículo continua con una exposición elemental de la teoría de la información y se termina con un estudio de los medios de mejorar las informaciones buscando el sistema de codificación más económico.

What is Cybernetics ?

H. Frank

(Summary)

An historical study of this concept leads the author to define cybernetics as the theory of the operational possibilities of information systems, the application of this theory to existing systems, and the methodical creation of new systems with a view to reaching definite objectives. Cybernetics is thus based on the general theory of information, the theory of information systems (data-handling theory), the theory of relations with the outside world (adaptation, regulation) and that of the complicated systems governing the subject as a whole.

The article continues with a statement in simple terms of the theory of information, and ends with a study of ways and means to improve information by using the most economic coding system.

Mathematics and School Biology

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1. Introduction

The major contribution of biologists to Victorian culture was the development of the concept of evolution supported by comparative morphological studies. *The Origin of Species* and the *Descent of Man* pervaded the intellectual life of that time. Thus, it was entirely reasonable that T. H. Huxley should commend to educators a course of biological training based on morphological patterns or types.

At the present time the impact of biology is derived from a much broader study of the processes of life, their origin, maintenance and interaction. It can be said, for example, that "Crystalline" viruses have replaced *Euglena* as the enigma of the day, and vitalism has given way to active transport, and that "Ecology is essentially a numerical subject". This has meant that the once obvious cleavage between biology and the other sciences has become blurred and, in particular, that the increasing relevance of mathematical knowledge, concepts and methods to biological study cannot be ignored.

This problem has influenced the thinking of many groups concerned with developing new biology courses and has even led to the admission by some university professors of biological science that they would prefer students to enter their departments with physics, chemistry and mathematics at A-level even if it results in the exclusion of any A-level biological study. While it may be contended that the arguments used to support this opinion are inadequate (Kelly, 1967), it is nevertheless symptomatic of the present malaise of school biology.

The proper relationship between biology as a discipline practised by biologists and biology as a component in the educational experience of young people is not easy to define and even more difficult to work out in practical details. It is, for instance, a sad paradox of elementary biology teaching during the first half of this century that, while it was based largely on the concept of

evolution, few pupils acquired more than a glib understanding of the topic. Our present dilemma is to ensure that, in our attempts to modernize biology education, we do not make decisions that will lead to a parallel situation arising in relation to the physical science and mathematical aspects of the subject.

The introduction of mathematics presents a special problem, not necessarily because of any inherent difficulty but because biology has for so long been looked upon as its educational antithesis. It can be argued that this attitude is based on false or unwarranted assumptions but, nevertheless, it remains a serious impediment.

The future biologist clearly needs to know some mathematics. It is also important (some would say more important) that, purely from the point of view of general education, we should all realize that, on the one hand, many aspects of life, which we are so keen to keep qualitative, are amenable to quantitative interpretation and, on the other hand, that there are recognizable limits to these interpretations. Furthermore, we have to face the fact that with some biological topics (growth and genetics, for example) mathematics is essential for their understanding.

2. The Relation between Mathematics and Biology at the School Level

A. *The function of mathematics in biology*

For the biologist, mathematics has three major functions. The first is concerned with measurement and computation and already finds a place in most school biology courses. The other functions are description and evaluation. These are rarely encountered and yet are as much a part of biology as anatomy or any of the more obvious topics.

A. W. H. Van Herk in an extremely interesting contribution to the O.E.C.D. publication *New Thinking in School Biology* (1962) outlines situations in which mathematical thinking is used by biologists.

“Originally . . . (he says) . . . the relevant logical concepts, essential for deducing hypotheses and experimental results, were of a relatively simple nature and likewise intimately allied to the familiar way of thinking. Later on it was found that in several branches of biology the familiar language could be replaced successfully by special notations as an alternative to lengthy descriptions for recurring and important situations, as in mathematics.”

Such a statement can apply to many biological topics. They include growth phenomena, the reactions of various types of kinetic processes in the cell under the influence of different environmental conditions, fluid mechanics, sensory physiology, genetics, and particular applied biological fields such as fisheries and pest control. The purpose of the link thus established between mathematics and

biology is to “promote accurate disciplines and clear thinking . . . to stimulate precise, objective, description of facts and hypotheses and to help (the student) to understand the results obtained in (these) branches of biology”.

This descriptive function can be seen to have both static and dynamic aspects. In the former sense mathematics is used as a form of short-hand and as an aid to understanding. The use of simple equations and graphs for describing population growth is an example. In a more dynamic way it is used to formulate hypotheses in the form of mathematical models. For example, the equation

$$F = \frac{KP}{R\eta} \dagger$$

can be used to describe the rate of flow (F) through a blood vessel and it provides a mathematical model of the process. It is incomplete because it assumes a steady flow of blood in an inextensible vessel. However, it enables the influence of other factors to be determined, e.g., comparing expected rates of flow as determined by the equation with actual rates.

Van Herk also deals with the evaluation function concerned with

“ . . . the reliability of interpretation of experimental data and of hypotheses. Both the impossibility of observing all conceivable events and the variation existing among those which are observed leads to a degree of uncertainty in any conclusions that are drawn. Chance is involved in supplying the essential information and is the cause of the uncertainty. In these and similar cases, especially where the collection and interpretation of numerical data is concerned, statistics appears to be a valuable supporting science in evaluating the reliability of experimental results, all the more since the small sample theory was developed, proving more adequate for biological research than the former large sample theory.

It is obvious that statistical research methods are almost equally important for all biologists dealing with problems of reproductibility of experimental findings whether they are geneticist, physiologist, ecologist, taxonomist, animal behaviourist, etc.

Closely related with the problems concerning the reliability of results are those dealing with designing of experiments. Since the inferences that can be drawn from the results depend on the way in which the experiments are carried out, special attention has to be given to their logical structure.”

A third situation to which Van Herk draws our attention is the “general nature of the processes involved in the achievement of the complicated internal harmony of an organism”. He suggests that the newer mathematics of information theory and cybernetics might help in our attempts to understand the regulation of the complicated interaction of the components of living systems. However, this is an aspect that need not worry the school biologist, at least in the immediate future.

† K = a constant, P = pressure, R = resistance, η = coefficient of viscosity of fluid.

B. *The conceptual relations of biology and mathematics*

Context

The scientist creates a world which, like the changing picture of a kaleidoscope, is not fixed. It is the best model of reality which can be derived from the information available. It will be modified as new facts become known. The scientist's model must be both internally consistent and externally consistent, i.e., consistent with new observations on the real world.

The mathematician although, in part, concerned with describing the real world, is very much more than the scientist, involved in devising possible worlds, which are logically ordered and founded on axiomatic, self-evident truths. On the whole, external consistency is of less concern to the mathematician than the scientist. It is in this way that we can talk about mathematics being abstract whilst science is to do with reality.

It is a growing conviction amongst many mathematics teachers that experience with real objects and events in the child's environment should be the starting point for the growth of mathematical ideas. They recognize, as have many biology teachers, that it is the abstract complexion of mathematics that alienates so many pupils.

There seems to be an interesting parallel between the child trying to comprehend the work of external stimulation and the scientist exploring the same world by more sophisticated techniques. Both have problems of learning and using systems of communication by means of which they may make their thoughts intelligible, and which they can use to describe hypothetical models which are testable against experience.

Mathematics can be integrated into both these processes and there is growing evidence, both from the experience of scientists and curriculum development projects in mathematics and science, that, when this is done, much of the antagonism towards the subject is lost.

There seems little doubt that by intimately relating mathematics to real biological contexts the problem of introducing mathematical thinking into school biology can be made less formidable and, incidentally, this is strong support for the view that biological mathematics should be taught by biologists rather than mathematicians.

Modes of thinking

Another way in which mathematics is said to be abstract relates to the form of imagery required to understand it. It is essentially non-verbal. School biology has traditionally been verbal in character, dealing with words rather than symbols. If mathematical topics are introduced will this provide insuperable obstacles to the pupil with verbal rather than non-verbal abilities? There has been little specific research on the abilities of pupils studying biology but it is possible to consider this question in general terms.

First it is important to realize that the distinction between verbal and non-verbal types of pupils is not a straightforward one. Obviously there are no pupils that are purely "verbal" or "non-verbal" and, at the level of treatment of mathematics that one would expect in a school biology course, the distinction between pupils becomes more one of general ability. Furthermore, as has been seen in a number of studies of pupil attainment, it is likely that interests, personality traits and background (the "X-factor") will be sufficiently powerful to make subtle distinctions between types of abilities largely irrelevant (Vernon, 1963).

Thus, provided the complexity of the mathematics introduced is not too high and there is a reasonable balance between verbal and non-verbal treatments of the material, there is little reason to suppose that if a school biology course contains mathematics it will discriminate against pupils other than through their general ability and motivation.

In one respect mathematics and traditional school biology call on similar abilities in the pupils. Both have aspects which require spatial and visual modes of thinking. For example, geometry and morphology clearly are similar in this respect. Here then is a possible way of easing mathematics into biology. By using, wherever feasible, visual presentation in the form of graphs, physical models, etc., one can take advantage of this common mode of thinking and thus reduce the apparent contrast between the subjects.

Transfer of training

The relationship between mathematics and scientific disciplines is often described as the application of mathematics. Unfortunately, this is frequently a relationship conceived from the point of view of the mathematician rather than the scientist and, we suggest, is a major cause of shortcomings in attempts, made in the past, to prescribe the content of mathematics courses to support a science. Such prescriptions often ignore two important and related principles. The first, that it cannot be assumed that transfer of training will automatically take place. Without conscious and organized links between the mathematics and the science it is unlikely that pupils will gain much benefit. The second principle is that any course must not only cover subject-matter but also provide motivation and organize the subject in a manner that is relevant to the pupils.

An extreme example of this misconception can be seen in the fate of the subject which has been described as "a branch of physics which became known as applied mathematics". In it there was little attempt to allow the results of deductive reasoning to be tested against bench experience as would be normal in a science and too frequently a series of unreal assumptions replaced observation. The emphasis was on the manipulation of abstractions which were meaningful to the mathematician, and not on real data which would have been relevant to the scientist.

A similar fate has been met by courses on mathematics for biologists and it has to be accepted that for success such courses need to have a clear biological context and be linked to mathematical treatments of topics in the biology course itself. In this way there is more hope of transfer of training and adequate learning and motivation being achieved.

C. *The reciprocal relation between mathematics and biology*

It would be merely compounding an error if we replaced the distinction between mathematics and biology by one between pure mathematics and biological mathematics. We need to lessen the distinction not to replace it by another. There are, of course, reciprocal links between the subjects and these are described in Fig. 1.

Although mathematics is used to interpret biological data, invariably at some stage in this interpretation mathematical relationships are used which are not directly related to the data. Furthermore those "pure" mathematical relationships can act as the starting point of an interpretation of a biological phenomenon as much as the phenomenon itself. The link between mathematics and biology is a two-way process:

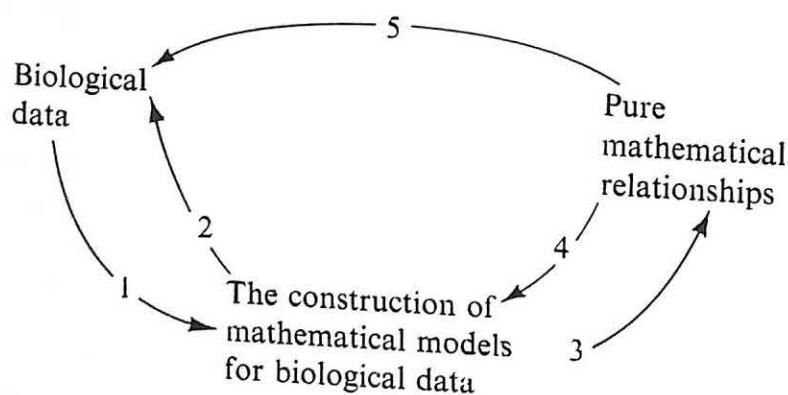


FIG. 1. The operational relationships between biology and mathematics.

Examples of each stage in the pathway can be given:

1. The construction of a growth curve.
2. The use of a growth curve in analysing the influence of environmental conditions (limiting factors) on growth.
3. The use of the normal curve distribution in statistics.
4. The manipulation of equations, i.e., $p+q=1$ and $p^2+2pq+q^2=1$, when dealing with problems in population genetics using the Hardy Weinberg principle.
5. The use of probability theory.

It is important that these relationships are made explicit to the pupil and this

is another reason for having both biological links in a mathematics course and mathematical links in a biology course.

D. *Some examples*

We present the following four problems in order to exemplify the ideas we have considered so far. The first two are rather elementary but show how mathematical ideas can be drawn from practical work.

1. *For young pupils*

Get pupils to measure the length of their middle finger from the centre of the knuckle to the tip. Plot the results as histograms for increasing numbers of pupils so that haphazard variation with small samples is compared with an approximation to a normal curve distribution when large numbers are used (Nuffield O-level Year 1, 1966).

In this way the key ideas of average measurements, dispersion and the importance of large samples when dealing with living materials can be established. This can be referred to when the results of investigations are analysed and used as a beginning to studies involving mean, standard deviation, standard error and sampling.

2. *For O-level and sixth form pupils*

Use different coloured beads to represent genes. By using containers to represent male and female organisms and large numbers of beads segregation and random recombination can be simulated and the role of probability in determining the frequencies of genotypes can be demonstrated. Such results can then be compared with data from actual breeding investigations (Nuffield O-level Year 5, 1967).

With advanced pupils the χ^2 test can be used to compare observed and expected results.

The next two problems are more appropriate for sixth formers and could be used either in an A-level biology course or in a complementary mathematics course. In both problems mathematics is used to develop models of biological phenomena which could be related to practical studies. At some stages the pupil is dealing with situations that are purely biological or mathematical and at others when the subjects are clearly linked. Visual and verbal, as well as non-verbal, mathematical interpretations are asked for and at times estimations rather than precise calculation are all that is needed. The second of these problems illustrates the evaluative function of mathematics.

3. *Growth of insects*

The increase of weight of *Dixippus morosus* during growth is plotted on the graph in Fig. 2.

- (i) Produce an equation by which the weight of an insect (of this species) at a given instar could be predicted, given the adult weight.

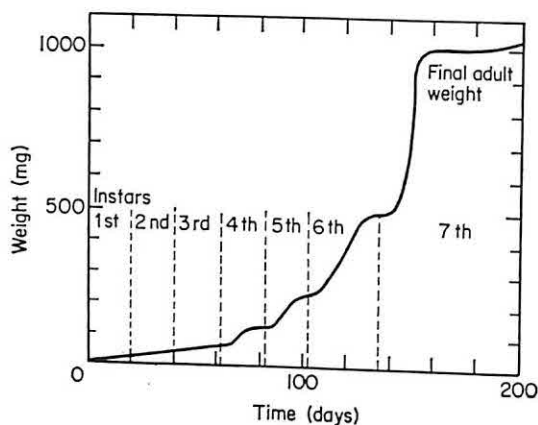


FIG. 2. Changes in weight during growth of *Dixippus morosus*.

- (ii) If a cube of sides x units doubles its volume so that its sides are now x_1 units long, what is the relationship between x and x_1 ? What factor would convert x to x_1 ?

Przibram found during his investigations on the growth of the insect *Sphodromantis* that the weight doubled during each instar and that at each moult all linear dimensions increased by the ratio of 1.26 or $3\sqrt[3]{2}$. Moreover, the number of nuclei per unit area of cuticle remained the same at every stage.

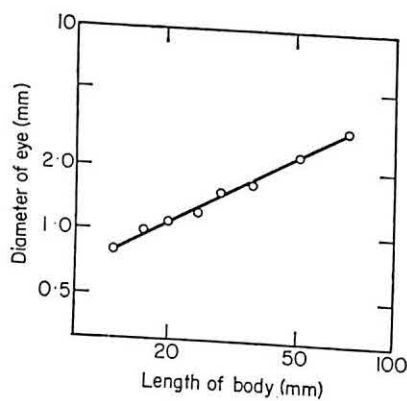


FIG. 3. The relation between the growth of body length and eye diameter in *Dixippus*.

- (iii) What is the simplest hypothesis which would account for these data concerning the growth of this insect?

In the *Muscidae* this numerical rule is obeyed approximately, but it has been established that after the embryonic period the cells do not divide, they grow in size only.

(iv) How do these facts affect the application of the hypothesis? Measurements made of the eye diameter of *Dixippus* and of the total length of body were plotted on logarithmic co-ordinates illustrated in the graph of Fig. 3.

Study the graph.

(v) Describe (a) in words, (b) as an equation, the information in this graph.

(vi) How does the information given, lead to a rejection of Przibram's simple rules?

4. Variation in style length in primroses

The histograms in Fig. 4 show the results of a study made in April and May 1966. The measurements of style length were made with dividers from the top of

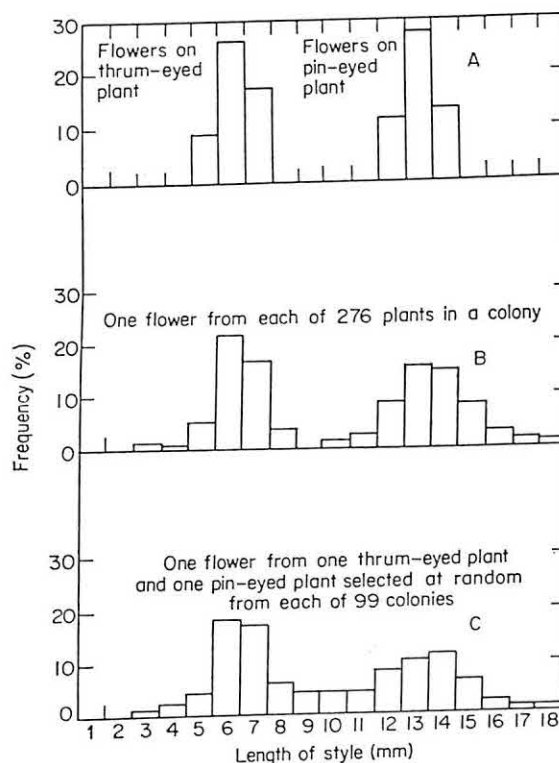


FIG. 4. Variation in style length in primroses (*Primula vulgaris*).

the ovary to the bottom of the knob-like style. Class intervals of one millimetre, e.g., 5.5–6.5 mm were used. Three separate studies were made, viz.:

1. Variation in style length of the flowers of two plants, one thrum-eyed and one pin-eyed.

2. Variation in style length of one flower from each plant in a large sample of plants from a single colony.

3. Variation in style length of one thrum-eyed flower and one pin-eyed flower selected at random from each of a large number of colonies.

This study of the primrose gives a quantitative expression to what is already obvious qualitatively, namely that there are two kinds of primrose flowers, those in which the stigma is placed below the ring of stamens—the thrum-eyed flower—and those in which the stigma is placed above the stamens—the pin-eyed flowers. This heterostyly, as it is called, is a device which secures a high degree of cross-pollination and is associated with differences in pollen shape and germination. Occasionally plants are found in which the stigma is at the same level as the stamens; such plants are known as homostyle plants.

Consider the histograms and answer these questions. Comment on the reasons for your answers.

(i) Do the histograms indicate that two quite different types of primrose flowers with respect to style length exist?

(ii) Is length of style genetically or environmentally determined or both?

(iii) If the last, suggest which exerts the greater influence, heredity or environment.

(iv) Give the median values of the six distributions.

(v) Work out the standard deviations of each of the six distributions. (What did you do about the four representatives in the 9.5 mm class in the third histogram?)

(vi) Would you expect the standard deviation of the distribution of the pin-eyed flowers to be greater than, less than, or roughly the same as, that of the thrum-eyed flowers?

(vii) Is there any evidence that some of the flowers were homostyles?

(viii) What conclusions do you draw from the fact that the standard deviations of the second pair of histograms are greater than those of the first pair and in turn are less than those of the third pair?

(ix) If this is a special case of a general phenomenon what general statement would you make about the variability to be found in an isolated population?

5. *What mathematics is needed?*

The mathematical content of the Nuffield O-level biology course is analysed in Table 1. Each mathematical topic is listed only in the year in which it first appears.

The approach of the Nuffield course, especially in years 3–5, is certainly much more quantitative than most previous O-level courses. Furthermore, it includes descriptive and evaluative mathematics as well as computation. Yet the range of topics covered is small and the level of difficulty usually below that expected in parallel O-level mathematics courses. Most of the topics are included in all O-level mathematics courses and the few exceptions, e.g., probability, are to be found in most of the newer syllabuses.

At O-level it would seem that the mathematical requirements of pupils taking biology can be met within the biology course, and the dependence on

MATHEMATICS AND SCHOOL BIOLOGY

mathematics courses *per se* is negligible. The same also appears to be true of C.S.E. courses.

TABLE 1

Mathematics in the Nuffield O-level biology course

Year	Mathematics	Examples of biological topics in which it is used
1	Measurement: length, area, volume, weight, magnification Fractions Frequencies Variation Average/mean Ideas of dispersion about a mean Tabulation: continuous and discontinuous distributions, histograms and normal curve derived from data Arithmetic graphs (two axes: curves and straight lines) Rates	Growth of plants and animals Cells Height and finger length of man Growth of locusts at different temperatures
2	Ratios and proportions Relative relationships Simple equations Area and volume Shape and movement relationships (visual demonstration only)	Elementary microbiological experiments Shapes and size of plants and animals
3	Percentages The parallelogram Correlation (scatter diagram, <i>not r</i>) Elementary sampling and calculation of population size	Gaseous exchange Action of ribs in breathing Smoking and health Ecological distribution of organisms
4	Elementary idea of feedback relations	Function of the kidney
5	Idea of algebraic models Probability (sum and product rules) Elementary permutation and combination Idea of exponentials $p^2 + 2pq + q^2 = 1$ Standard deviation	Single factor inheritance Growth Hardy Weinberg Genetic code

At the present time, the introduction of mathematics into biology courses at A-level appears to be more a problem of tedium than difficulty. As more emphasis is put on the analysis of experimental results, there is a tendency for the load of relatively simple computation to become greater and a fine balance has to be achieved so that the development of biological concepts is not confused by

arithmetic. It would seem far more important that emphasis should be put on mathematical description and evaluation. Many of the topics in the new biology syllabuses lend themselves to this treatment. Table 2 indicates some of the mathematical topics that might be considered appropriate for inclusion and, indeed, necessary if the biology is to be adequately comprehended.

TABLE 2
Mathematical topics of use to A-level biology

Mathematical topic	
Description	The idea of parameters and variables Graphical representation Measurement of variation (σ , normal curve, area under a curve) Logarithms, exponentials Compound interest Trigonometrical relations, e.g., sine, cos, tan. Linear and quadratic equations The binomial expansion
Evaluation	Sampling Probability (sum and product, the binomial expansion) Standard error Tests of significance (t and χ^2 without proof)

Although the topics cannot be considered excessively difficult in a sixth form context, at the moment biology teachers may not be familiar with some of them. Furthermore, if they are to be fully appreciated by pupils, time is needed for regular exercise in their use; time which quite reasonably is not available in the biology course itself. A set short course on mathematics for biologists is not necessarily the best answer. What is required is a more flexible arrangement whereby the topics are introduced within the context of the biology course and pupils are then given exercises in private study and homework and have the opportunity to discuss these with both biology and mathematics staff. Time will have to be allowed for this but through this method—as has been shown by some schools already—it is possible to make the relationship between the two subjects apparent to the pupils.

Finally let us consider the needs of those pupils who intend to proceed to higher education courses in biology or related subjects, e.g., medicine, pharmacy and agriculture. The proposition that for such students, mathematics should be related as closely as possible to the subject in which it is used, applies as much in higher as in school education. However, in higher education there is a greater

need for the scientist to have an understanding of the mathematics of the mathematician in order to appreciate not just that mathematics can be used in his subject, but sufficiently *how* it is used, so that he can ask the right sort of question when he consults with the mathematician. It is in higher education that the real need for mathematics courses for scientists lies.

Can a mathematics course in the sixth form help in providing a grounding for such work? This, we suggest, depends on two important provisos. First, that the

TABLE 3

*Some outline mathematical topics required by biology students
in university and comparable courses*

Elementary algebra, trigonometry and geometry
Set Theory
Probability
Decimals
Binary numbers
Calculus in one variable: differentiation and integration
Arithmetic and geometric series, logarithms, exponentials
Geometry of three dimensions
Trigonometrical functions: equations of straight line and three dimensions
Matrix algebra
Differential equations
Statistics:
frequency distribution; central tendencies and dispersion (e.g., mean, σ); regression; correlation; sampling (related to probability and binomial distribution); Poisson distri- bution; standard error; significance (e.g., χ^2 and con- tingency tables, t)

mathematics taught in the sixth form is used in the first year of higher education: otherwise the process will be inefficient because, inevitably, much will have to be retaught and certainly relearned. Second, that the mathematics is relevant and does not impose an excessive load on the pupils timetable otherwise work in the biological and physical sciences is likely to be impaired.

In Table 3 we list those mathematical topics that would seem to be necessary for the biologically inclined student at university level. Some of the topics are extensions of those already suggested for the sixth form biologists. Some—and integral calculus is a particular case—would not be covered earlier and are subjects that, unlike most of those we have previously considered, cannot be so easily derived from a biological context. They need to be considered as mathematics *per se* and then applied to data. This is the other side of the reciprocal relationship between the subjects.

Such topics could be taken in a specially designed course. It is not necessary for this to be equivalent to a full A-level subject and it could also be taken by

pupils taking physical science, economics and other subjects. Alternatively, pupils requiring this level of mathematics could take A-level courses such as those devised by the Schools Mathematics Project which include most, if not all, of the topics listed.

At the same time there will still be the need to set the mathematics in an appropriate context for the biologist. It will not always be possible to do this within a main course in mathematics because of pressure of other obligations but if a system of informal study and consultation such as already referred to (page 82) is adopted, the links between the subjects can be established.

3. Future Research

The optimum conditions for learning to use the methods and concepts of mathematics necessary for the understanding of quantitative aspects of biology must be the subject of research rather than argument. The components in this problem are the students, biology teachers, mathematics teachers and the nature of the communication established between them. The biology teacher must identify those aspects of biology which will be better understood when mathematical concepts and methods are used. He must engender motivation in his pupils by demonstrating the relevance of quantitative thinking to the problem under consideration. The mathematics teacher must be acquainted with the biological problem so that the growing points may be identified. The pupils must be encouraged to test their new understanding against experience in the laboratory and field.

Some progress has been made in providing materials which might play a part in such a curriculum development. For example Bishop (1967), Dowdeswell (1967), Greig-Smith (1964) and Lewis & Taylor (1967) provide useful ideas in statistics. Eggleston (1968) covers a larger field. The Nuffield A-level Biology Project is also concerned with the problem.

Self-instructional methods, e.g., programme learning and the use of television and radio series such as the recent "Mathematics in Action" (BBC), have also a large part to play.

The problem is beset with difficulties—intellectual, personal and organizational. Both biology and mathematics teachers will need to be cast in the dual role of specialist and consultant, one obviously different from the usual specialized expository role.

However, the problem has much wider implications and there is a need for a carefully evaluated curriculum project covering the total problem of the relation between mathematics and those subjects of the sixth form curriculum that depend on it. So far curriculum projects have been largely concerned with developments within already established subjects. For this problem we need to take a much wider, inter-subject view.

We will also have to look carefully at the role of examinations. Can they be made sufficiently flexible to fit in with such a scheme? Can we depart from the idea (implicit rather than explicit in our attitudes) that examinations are the end-point of a course and conceive them as assessments of a pupils attainment irrespective of how it is attained?

4. Summary

1. Irrespective of their future career school pupils taking biology need to know some mathematics.

2. There are some aspects of biology, even those encountered at an elementary level, which require mathematical thinking for their understanding.

3. The relationship between biology and mathematics is a two-way relationship. While it is true that some biological concepts and methods require mathematics for their understanding, it is equally true that biological data and problems can provide circumstances in which mathematical methods and concepts can be learnt.

4. The growth of mathematical concepts in a biological context has several special features. Two of these features have been discussed as potentially important. The first is the use of mathematics as a means of describing hypothetical relationships between variables—mathematical models (the descriptive function). The second feature is the importance of testing such models against the reality of new experiences (the evaluative function).

5. In order to facilitate the transfer of mathematical skills and concepts to biological problems it is suggested that a close consultation should be established between the teachers of biology and mathematics and the biology students. It is suggested that auxiliary mathematics courses conceived in isolation are not the most suitable way of tackling this problem.

6. The problems of the deployment of time and resources so that skills and concepts once learned are not lost are briefly considered. The need for new resources and a more imaginative use of existing resources may be necessary for establishing conditions in which learning and reinforcement can occur.

7. Attempts have been made to list mathematical concepts and methods which may be appropriate at O-level and A-level. Some examples of problems are given which partly illustrate the way the relationships between the two subjects have been explored.

We are grateful to W. H. Dowdeswell, R. E. Lister and D. Wheeler for their comments and to L. C. Comber for permission to use Problem No. 4 on page 79.

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(Résumé)

1. Indépendamment de leur future carrière les élèves se dirigeant vers la biologie ont besoin d'avoir des notions de mathématiques.

2. Quelques aspects de la biologie, même à un niveau élémentaire, requièrent des connaissances mathématiques pour leur compréhension.

3. La relation entre la biologie et les mathématiques est une relation à double sens. Alors qu'il est vrai que des concepts et des méthodes biologiques ont besoin de mathématiques pour leur compréhension, il est également vrai que des données et des problèmes biologiques peuvent fournir des faits utiles à l'enseignement des mathématiques.

4. Le développement des concepts mathématiques dans un concept biologique a plusieurs caractéristiques. Deux de ces caractéristiques ont été débattues comme virtuellement importantes. La première est l'emploi des mathématiques comme moyen de décrire des relations hypothétiques entre des variables - modèles mathématiques (fonction descriptive). La seconde caractéristique consiste à tester de tels modèles par rapport à de nouvelles expériences (fonction évaluative).

5. Afin de faciliter le transfert de compétences des concepts mathématiques aux problèmes biologiques il est suggéré qu'une réunion restreinte puisse être établie entre les enseignants de la biologie et des mathématiques et les étudiants de biologie. Il est également suggéré que des cours supplémentaires de mathématiques, conçus séparément, ne résolvent pas le problème de la meilleure façon.

6. Les problèmes que les compétences et les concepts une fois enseignés ne soient pas perdus, sont brièvement étudiés. La recherche de nouvelles méthodes et un meilleur emploi des méthodes existantes est nécessaire pour que l'enseignement et son renforcement puissent être effectués.

7. Des essais ont été faits pour englober les concepts et méthodes mathématiques qui peuvent être affectés aux niveaux O et A. Des exemples de ces problèmes sont donnés qui illustrent partiellement les relations entre les deux sujets.

Las matemáticas en la enseñanza de la biología

J.F. Eggleston y P.J. Kelly

(Resumen)

1. Independientemente de su carrera futura, los alumnos que se orientan hacia la biología tienen necesidad de nociones de matemáticas.

2. La comprensión de ciertos aspectos de la biología, incluso en el nivel elemental, requiere conocimientos matemáticos.

3. La relación entre la biología y las matemáticas es recíproca. Si bien es cierto que la comprensión de los conceptos y de los métodos biológicos tiene necesidad de las matemáticas, no es menos cierto que los datos y los problemas biológicos pueden aportar hechos útiles para la enseñanza de las matemáticas.

4. La aplicación de los conceptos matemáticos a un concepto biológico presenta varias características, dos de las cuales son particularmente importantes. La primera es el empleo de las matemáticas para describir relaciones hipotéticas entre variables: modelos matemáticos (función descriptiva). La segunda consiste en verificar esos modelos con relación a nuevos fenómenos (función evaluativa).

5. A fin de facilitar la transferencia de los conceptos matemáticos a los problemas biológicos se propugna una reunión restringida entre los profesores de biología y de matemáticas y los estudiantes de biología. Al mismo tiempo se señala que los cursos suplementarios de matemáticas, concebidos por separado, no son la mejor solución de ese problema.

6. Se examinan brevemente los problemas relacionados con la conservación de la capacidad y de los conceptos enseñados. Para iniciar esa enseñanza y mejorarla gradualmente es necesario formular nuevos métodos y aplicar los existentes de una manera más eficaz.

7. Se han hecho ensayos para englobar los conceptos y los métodos matemáticos aplicables a los niveles 0 y A. Se dan ejemplos de esos problemas que ilustran parcialmente las relaciones entre las dos disciplinas.

Section 3 / Partie 3

EDUCATIONAL METHODS AND TECHNIQUES /
METHODES ET TECHNIQUES PEDAGOGIQUES

LABORATORY EXERCISES IN SENSORY PHYSIOLOGY AND IN BEHAVIOUR

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One of the most important aims of biology is to understand how and why a living organism behaves in a special situation. Until the 1950's the elements of the complex behaviour had merely been cataloged, ordered, and comparatively studied. The time has now come to change into physiology of behaviour. Biologists are working together with physiologists, biochemists, psychologists, experts in Cybernetics to explore not only the elementary processes in the receptor and in the nerve cells, but to understand too those mysterious processes - which we call mood, learning, formation of memory - and to influence them by psychopharmaca. Therefore it seems absolutely necessary for the student of biology to get a solid training in the physiology of the sense and of behaviour. To realise this, he must learn its methods by practical experiments. What follows here gives a first introduction. No complicated and expensive apparatus is required and the exercises can be done in every country of the world. There will be no difficulty either in finding the animals necessary for these experiments.

The whole course will be divided into three parts :

- 1st - optical senses
- 2nd - chemical and mechanical senses
- 3rd - complex behaviour (especially reproduction and social behaviour).

I - THE BEHAVIOUR OF PROTOZOA

Every living cell must be able to receive information and to understand the signals from the environment. This environment can consist of other cells of the same body, or it may be another individual or it may be non living matter. Irritability can most clearly be studied in the protozoa. Here a single cell has to receive all the stimulations in order to transform them, and to respond with a correlated behaviour.

Exercise 1

Chemotaxis of Paramecia

The living conditions of Paramecia are confined in a small range of pH. Put a drop of a culture of Paramecia onto a slide. You will observe

under the microscope that the animals are swimming irregularly distributed in the water.

Place on the slide with a capillar pipette a small drop of acetic acid (about 0,01 % concentrated), which is slightly tinged with "Kongo-Red".

Result : If you have choosen the right concentration of acid the animals gather in the coloured drop. (The best concentration is, when the Kongo-Red just changes from blue to red, fig. 1a).

We now choose acetic acid of 0,5 % concentration (Kongo-Red has changed its colour to blue). In a certain zone around this drop of acetic acid the Paramecia gather in a condensed ring. This is again the optimum of pH (fig. 1b).

The animals are caught in this zone. We try to follow one of these protozoa under the microscope (fig. 2) : by chance it comes into the zone of pH-optimum, as soon as it touches the border of this zone, a phobic reaction can be observed (Phobotaxis), which compells the protozoa to retreat. This is the most primitive kind of orientation, which can be imagined : flight reaction, when an unfavourable zone is perceived.

The same experiment can be made using a salt solution.

Put a crystal of table salt (NaCl) into the center of the slide : in the beginning there is flight reaction around the crystal ; when the crystal has dissolved the Paramecia gather in the zone of the optimal salt concentration.

Exercise 2

Thermotaxis

a) A heating-wire is fixed on a slide (fig. 3) : if you switch on the current (use a battery of 2 volts for a 0.2 mm thick platinum wire) the Paramecia withdraw more and more from this expanding area.

b) The just mentioned experiment can be done with a more exact method, by which the drop is divided in gradually varying temperature zones (fig. 4). A strip of copper foil cooled with ice water contacts one extremity of the drop containing the Paramecia ; another strip of copper foil, heated with warm water, contacts the opposite extremity of the drop. After a while the protozoa gather in the temperature optimum.

Exercise 3

Galvanotaxis

This experiment demonstrates that electric current directly influences the movement of the cilia. The physiological causes are still un-

known. When *Paramecia* are put between two electrodes, which have 8-12 volts/cm (fig. 5), the animals swim to the cathode. One observes under the microscope that a small part of the surface cilia, which are orientated to the anode are moving backwards, as the animal normally does. The resulting movement is towards the cathode (Galvanotaxis).

II - OPTICAL SENSES

Light - dark reaction

The most basic capacity of optical receptors is to distinguish light and dark. Primitive "eyes", light sensitive single cells distributed over the whole surface of the body, are sufficient for this task.

Exercise 4

An earth-worm (*Lumbricus*) creeps through a glass tube of about 1 cm diameter. 15 cm of the tube are covered with black paper (fig. 6). The animal will get at rest in the dark region of the tube. Now we remove the paper a few centimetres so that the front end of the animal is exposed to light. The earthworm will immediately retreat into the dark region. The same will happen, if the opposite end of the animal is exposed to light; the reaction, however, is slower.

Record the speed of reaction

- a) when the anterior segments
- b) when the posterior segments and
- c) when the middle region of the body is exposed to light.

Compare the reaction times of the various regions with the number of photoreceptor cells in the respective regions of the skin; these receptors can be found in sagittal sections (6u) of the front end (fig. 7).

Determine the relationship between the reaction and the intensity and the wave length of light.

Photoreceptors and direction of light (klinotaxis, tropotaxis)

An important advance in optical orientation is made if - beside light-dark discrimination - the direction from which the light comes can be determined. This performance can be achieved either from the organ's shielded position in the body or from a pigment layer. The elementary form of such directional orientation is called klinotaxis.

Exercise 5

Klinotaxis

Euglena viridis has a light-sensitive stigma at the base of the

flagellum ; the animal swims in a positive phototaxis to the light source using the sunlight for photosynthesis. Fig. 8 shows that it does not swim directly to the light but in pendular or spiral movement comparing intensities at successive points of time. By this pendular movement around the main direction of light it finds its way to the light source (klinotaxis) ; (position 1-2 : light from above ; position 3 : light from the right side ; position 4-5 : light from below).

Exercise 6

Larvae of flies react in a negative phototaxis ; they withdraw from the light in a klinotactic way. The light-sensitive receptors are situated at the front end of the body without a pigment shield. In a dark room larvae of *Calliphora*, *Lucilia*, *Drosophila* are put on a leaf of wood covered with filterpaper. The animals are exposed to light coming flatly from one side (by a low voltage lamp). Observe the movements of head and body during the klinotactic orientation. Switch on another lamp, which is located at an angle of 90° to the first one. Switch off the first lamp. What will happen, if the two lamps have a different intensity ? Calculate the resulting direction of orientation, examine the significance of difference!

Tropotaxis

If the animals possess a pair of well shielded eyes, the individuals move directly towards the light source. This orientation is called tropotaxis. Both eyes are exposed to light in such a way that the stimulation of the receptors is equal. The animal moves to the source like a horse directed with two bridles, by simultaneously weighing the information coming from the right and left side.

Exercise 7

A bee is positively phototactic, when it is in the mood of fleeing. We lock some bees into a small cage and shake the box slightly or tap on it with the fingers to startle the animals. Then we let them free at constant intervals. They fly directly to the light (to a small window or to an artificial light source ; an electric lamp must be shielded by a gauze, otherwise the animals will be burnt).

Note : Only in specific mood (fleeing ; searching food) the bees are positively phototactic ; in homing or in low temperature the behaviour is changed into negative phototaxis (see Exerc. 10).

Exercise 8

Planaria possesses two cup-eyes (check with the microscope that the light is shielded by the pigment cup ; light-sensitive cells are located in the middle of the cup only). In intense light the *Turbellaria* react in a negative phototaxis ; they withdraw from the light source in a rectilinear way (fig. 9). Change the position of the light source through varying angles (90° , 140° , etc) and register, how the *Planaria* change their direction ! (R_1 , R_2 , R_3 , R_4 : light source).

Exercise 9

One of the two eyes is eliminated by a needle under the microscope. Light comes from above : the Planaria creeps in a circle, always to the side, where the eye has been operated (fig. 10).

Exercise 10

A glass basin is exposed to intense light on one side, and we put Daphnia into the basin and observe that the animals are equally distributed in the water. If the intensity of light is gradually decreased the Daphnia become more and more positive phototactic ; they swim toward the light.

The same reaction can be observed, if CO₂ is slowly introduced. (Be careful, for the animals will be narcotised at a high concentration!).

At the same time the Daphnia ascend a bit in a negative geotaxis. Which biological meaning has this striking mood-linked phototaxis ?

Exercise 11

Transverse phototaxis

Positive and negative phototaxis are the most primitive forms of orientation to a light source. Evolution has lead in an ascending way to menotaxis : By this not only 0° - and 180° - direction, but also every possible angle to the light source can be chosen and maintained for a direct orientation. That is important, the light source, however, changes its position (sun compass orientation of arthropods and birds).

Between positive or negative phototaxis and menotaxis an intermediate orientation can be found in the transvers phototaxis in many crustaceans (fig. 11).

The menotactic position toward the light again can be influenced by the mood and by the intensity of light : we put Daphnia or Artemia or Mysis into a glass basin. We gradually vary the intensity of light, which has caused firstly transverse phototaxis, Artemia and Daphnia swim in menotaxis toward the surface ; if you increase the light, the animals swim menotactically toward the bottom (fig. 12).

Pattern Recognition

An essential advance in evolution is made, when the eyes are not only able to recognize the direction from which light comes but also the pattern of light. This performance demands the following prerequisites :

1. The image must be projected sharply on the retina.
2. There must be enough receptive elements to divide the image into many single spots (principle of vision).

3. These single spots of the image must be arranged again by the central nervous system to a whole, to one form ; they must be integrated into one "Gestalt".

The following experiments have to prove, that bees and cuttlefishes are capable of such remarkable performance.

Exercise 12

We offer a group of bees the form 1a in fig.13 as food-signal ; on a horizontal table the bees can suck sugar solution from a watch glass just in the center of fig.1a. If we give in the test (when no food is offered) other forms of the lower row and form 1a to choose between, the animals confound these forms. But the bees are capable of distinguishing them from the forms of the upper row. The consequence from these results is : not the exact geometrical form serves for the bees as criterion of the pattern but the richness of the contours of a form, or in other words : the richness of the contours of a form, or in other words : the "figural-intensity".

Note to the method of training the bees

We must try to allure the bees to our training table, on which the patterns are offered. We start by laying a cardboard with some drops of honey near to the entry of the hive. Soon some bees will find these drops of honey. We then carry this cardboard step by step - constantly giving food in intermediate stations - to our training table. Some of the collecting bees will return to the table and alarm other companions by dancing in the hive. It suffices, if we thus keep a group of 10-20 bees.

Exercise 13

Spontaneous preferences of "figural intensity"

We feed bees on a training table without forms of any sort . After a 1/2 hour, when the bees are familiar with the location of the food source we offer at once the patterns of fig. 14 - the whole table remaining without food.

Result : the forms, which have the gratest intensity of contours are spontaneously preferred. (Principle of "figural intensity").

Exercise 14

Angle discrimination on vertically orientated stripe patterns

Is the low efficiency of geometric form as we have seen in experiment 12, due to a defective visual acuity ?

We train to a transverse stripe, to a transverse pattern of stripes and to an oblique cross this time, however, not on a horizontal but on a vertical plane (fig. 15 and fig. 16). In the test the bees have

to choose between patterns which have the same shape as in the training situation but a different angle position in respect to the gravity.

Result : a small difference of the angle already suffices for the bees to distinguish between the right and the false forms. In fig. 16 the result and its explanation is given in detail. (R = positive reactions in the test ; training position of the forms 45°).

Exercise 15

Pattern recognition in Octopus

In pattern recognition of the cuttle-fish Octopus horizontal and vertical elements are decisive parameters too. Octopus is trained to a black rectangle in a vertical position. In the test it will be distinguished clearly from the same form but in horizontal position. Fig. 17 shows further pairs of forms and the corresponding results in vertical and horizontal position. (The columns on right indicate the predicted outputs).

Methodical explanation

Octopus is put into an aquarium, where it can hide behind stones or flower pots. In the opposite wall of the aquarium the pattern of stripes is offered, constantly moving up and down a bit. The animal will attack such moved pattern. If the right pattern is rewarded with a small fish and the false punished with an electric shock (2-4 volts), Octopus will very quickly learn to choose the right pattern.

Exercise 16

Repeat experiment 15 and observe exactly the position of the eyes. Octopus keeps the aperture of the eye in a strict horizontal position, when it attacks the test form. Destroy the organ of gravity. The aperture of the eye is no longer oriented to the field of gravity ; the slit follows the turning of the body. Now Octopus is no longer capable of distinguishing vertical forms from horizontal ones. This is not due to a general shock of the operation : the cuttle fish is still able to distinguish a black stripe from a black disc.

Perception of movement

Vision and its performance cannot be measured only in parameters of space (resolving power) ; it must be measured also by the parameter "time". The "optomotor reaction" will give the experimental basis.

Exercise 17

According to fig. 18 and fig. 19 an insect (a bee, a beetle, a locust, a fly) is put in the middle or in front of a vertically dark striped cylinder or plate. When the cylinder or the plate is rotated the animal follows this movement ; the animal tries to keep its visual field constant.

Often only the head or even the eyes follow the rotating movement. When the cylinder is rotated at such a speed that the flicker fusion frequency is surpassed, the tendency to follow the rotation ceases.

- a) Determine the flicker fusion frequency for bees, flies, etc.
- b) Compare these values with the corresponding one for man.

Exercise 18

A butterfly (Pieris, Vanessa, etc.) is fixed with its wings at a stand in the centre of a striped cylinder. The legs hold on to a small ball of cork. When the cylinder is slowly rotated the head of the butterfly (and consequently the antennae too) follow this movement. On the antennae you can measure exactly the smallest angle through which a stripe must move, in order that an optomotor reaction will be caused in the butterfly.

Exercise 19

Optomotor responses in crabs

A crab, *Carcinus*, is put into the centre of a rotating cylinder. When the cylinder is rotated, the eyestalks are moving along with the changing pattern. This can be measured quite exactly, if you fix on the eyestalk a wooden stick with a flag. The flag indicates, according to fig. 20, the movement of the stalks and is registered by a photo-cell and a pen recorder. Determine the "minimum separabile".

Exercise 20

Measuring the speed of the sun's angle of azimuth

A crab, *Carcinus*, is put into a tub, so that landmarks of the environment cannot be seen. Only the open sky and the sun are visible. The eyestalks move now with the apparent movement of the sun. If the sun is visible for the crab on the opposite side in a mirror and the real position of the sun is covered with a piece of cardboard, the animal changes its position according to the apparent position of the sun in the mirror. If you hide the sun altogether, the movement of the eyestalks is stopped.

Limit of sensibility : a movement of the sun for 10 seconds is compensated by a movement of the eyestalks !

Colour perception

Colour vision is most important capacity of the optical sense. Specific visual pigments, which decay through light, represent the physiological basis. In two simple but critical experiments of behaviour we will prove that bees and fishes are capable of colour perception. In a third experiment we will show, that bees are blind for red, but sensitive for ultraviolet.

Exercise 21

On a piece of blue cardboard a watch-glass with sugar water is placed. A small group of about 10 bees is trained on blue for several hours. It is by no means sufficient to let the bees choose in the test between blue and yellow for instance. For a colour-blind eye is able to distinguish these colours through the different intensity of light. (A black-white photo illustrates this fact).

We have to offer - both in the training situation and in the test - together with the blue cardboard a series of several grades of grey, one of which must have the light intensity of the blue being trained for (fig. 21). Make sure that the position of the blue cardboard and the grey grades are continually shifted about every 5 minutes during training time, in order to avoid training to a certain place. For the test you have to use a brand new series of grey and colour cardboards ; when the bees set down during the training, they leave scent marks on the blue cardboard, which may falsify the results. In the test, an empty, scentless watch-glass is placed on every one of the 16 cardboards. For 5 minutes we count the number of the bees which spontaneously land on one of the 16 fields. (Change the places of the coloured cardboard squares every minute. For every square there must be one observer).

Exercise 22

The human eye can distinguish colours from red to violet (wave length 750 nm until 400 nm). If we repeat experiment 21 with red cardboard, the bees mistake this colour for the corresponding grade of grey: they are red-blind. Their spectrum is shifted into the region of short-wave length, which may be established by the following experiment.

Exercise 23

On a black disc, which can be rotated, zinc-white and lead-white¹⁾ are offered in the form of two white stars (fig. 22). When training, the bees can drink sugar in the centre of the zinc-white star through a capillary glass tube. To avoid training to the specific location, the disc is turned after short intervals. In the test the training places are covered (to avoid scent marks) and two new stars - lead-white and zinc-white - are offered without food.

Exercise 24

Evidence of colour vision in fishes

For two weeks we offer a fish (e.g. Phoxinus) the usual food (raw, minced beef) in a colour cup in the aquarium (fig. 23/24). As in

1) zinc-white absorbs } Ultra-Violet
lead-white reflects }

the training of bees we offer at the same time several grey cups, one of which must have the same intensity of light as the colour dish. In the test all cups are without food. (Use new cups, so that no scent marks falsify the result). We count how often the fish snatches at the colour cup, how often he seeks for food in the grey cups.

Exercise 25

A histological section through the retina of this fish shows rods and cones as elements of vision. In the day animal - which alone is capable of colour perception - the cones are located in front of the pigment layer, the rods are hidden in the pigment.

We repeat the training of exercise 24, but do the experiment in a very dim twilight ; the fish does not perceive the colour it is to be trained to. A histological control shows that the cones are hidden in the pigment and the rods are located in front of that layer.

Consequence : Cones are especially for day-light and colour perception. Rods serve for twilight vision.

Perception of polarized light

Light, that comes directly from the sun to the earth, is depolarized, the rays oscillate in all directions. The blue sky, however, reflects polarized light to the earth. The plane of oscillation and the grade of polarization at every place in the sky depend on the position of the sun. That means : along with the changing position of the sun a differentiated pattern of polarization wanders over the sky (fig. 25). The bees use this pattern for their sun-compass orientation (see below), when the sun is covered by clouds. They can do this only if they are capable of analysing the plane of polarized light. They prove this capacity in the following experiment.

Exercise 26

Food is offered to bees in a light box ; in the front-wall where the bees arrive, three windows (5 x 5 cm) are cut. In these windows we put a polarizing foil. The bees get sugar water behind the middle window where the polarizing foil is offered in 0° position ; during the test this window is covered, in the left window a polarizing foil is lighted in a position of 0° , in the right window a foil in 90° position. The positions are exchanged during the test in intervals of one minute. The bees learn within some hours to distinguish the plane of oscillation of 0° from that of 90° .

Exercise 27

Polarized light is analysed in the bee's eye by the rhabdomeres, which with their microvilli are radially arranged in each ommatidium. The "star-foil", as a model of the insect's eye, shall show how the blue sky is seen by a bee.

We compose the star-foil out of a polarization foil according to the pattern of fig. 26. If we put a second foil in front of the star-foil and rotate it, the light pattern of the star-foil continuously changes (fig. 27, 28). We get the same result, if we keep the star-foil against the blue sky and check different parts of the sky and take a photo (fig. 29).

Sun-compass orientation

Many animals use for their orientation the sun as compass. The menotactic position towards the sun is presupposed, but it does not suffice. The sun is not a fixed light spot in the sky. It moves with certain speed of the azimuth's angle over the sky. Whoever uses the sun as a compass, must take into account this apparent movement of the sun. We will test, if the animals are able to do so.

Exercise 28

The beach flea (Talitrus), which can be found very often in the shores of warm oceans, is repeatedly driven to the dry beach by the breaking waves ; Talitrus at once flees back to the sea. The direction of flight is oriented according to the position of the sun ; this direction differs specifically for every population (i.e. for every strip of the shore can extend in various directions). We catch some Talitrus on the Beach, take them into the laboratory, place one of them in the centre of a plate, which is covered with moist paper marked with angles of the circle (fig. 30 : this figure shows the river spider "Arctosa" which uses the sun-compass in the same way, when it flees back from the open water to the protecting river). A wall of tin or cardboard prevents the animals from seeing landmarks. The crustaceans (or the spiders) will flee from the centre into a definite direction and we register the compass-direction with the help of the degrees marked on the paper.

Result : as long as the sun is visible, the animals flee in the same direction as on the shore ; if the sun is covered and visible through a mirror from the opposite side, the animals turn through 180° . If the sky is totally covered, the animals are no longer orientated. It suffices, however, if the animals can see a part of the blue sky, even if the sun is hidden behind clouds. The pattern of polarization suffices for sun-compass orientation.

Exercise 29

We perform experiment 28 in the morning, at high noon and in the evening : the sun's angle position changes, but the direction of flight remains the same, i.e. the animals take into account the apparent movement of the sun.

In a dark-room the sun can be substituted for by a small lamp. If the lamp remains in the same place, the animals change their direction of flight counterclock-wise during the course of the day. The Talitrus and the Arctosa do this as if they had taken into account the movement of the lamp with its corresponding speed of azimuth.

Exercise 30

We force ants (*Formica*, *Lasius*, etc.) to carry their chrysalis from the centre of an area into the next located at the edge. A wall of the area must hide the landmarks of the environment.

Young, unexperienced ants orient according to a constant angle of the sun and must learn in the course of some days or weeks to take into account the apparent movement of the sun. Then they show a true compass orientation.

Exercise 31

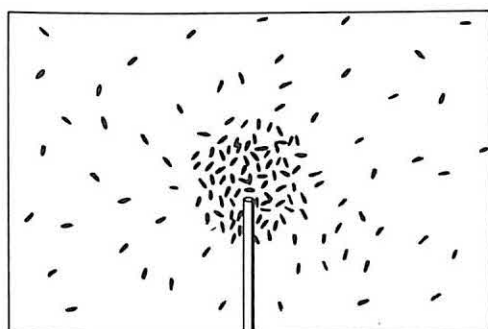
The Manitoba Fly Trap

This last experiment shall show, how one can ascend from pure basic research to applied biology.

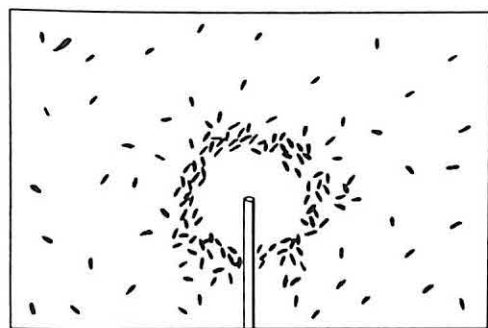
Blood-sucking insects are often attracted optically from the distance by the host (by the shape of its body, its movement or colour, etc.). When they approach nearer, the odour and radiation of warmth are additional lures. The dark contours of horses and cattle attract flies and breeze-flies from the distance. The exact shape of the body is not important.

A black plastic ball is a very effective dummy. It is warmed by the sun and allures the insects very near to our fly trap. The animals land on the ball and seek for a place to suck from. They fly off and come into the transparent plastic box; the flies push against the wall which release an escape reaction; they flee in a positive phototaxis and a negative geotaxis upwards. Thus they come into the poison-bottle at the top and can be counted.

Exercise : register the distribution of the sexes; how far does the captured number depend on temperature, sunshine, wind, season? Especially great numbers will be captured in a calm clearing of the wood in sunshine.



a



b

FIG. 1

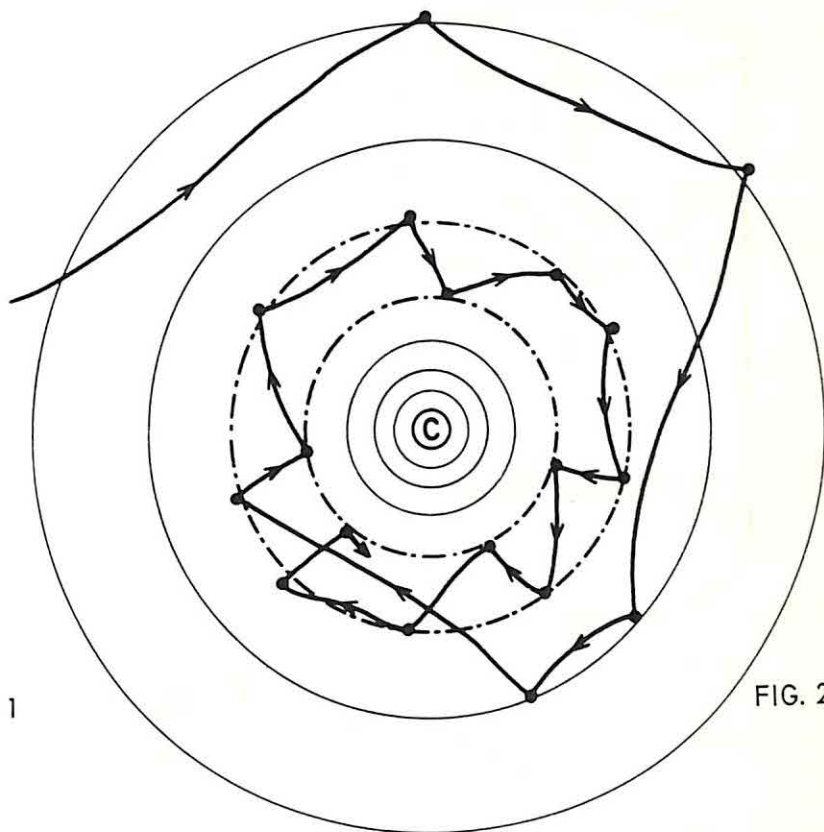
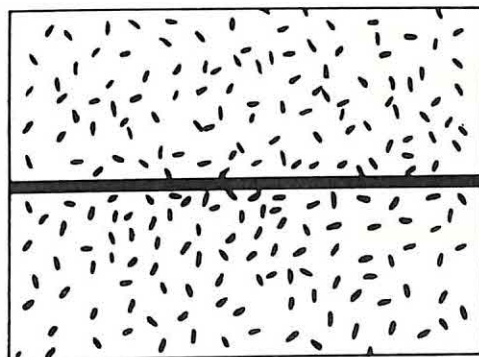
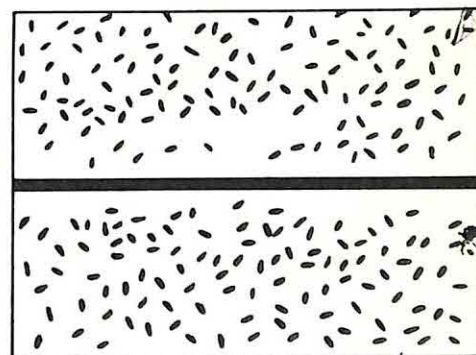


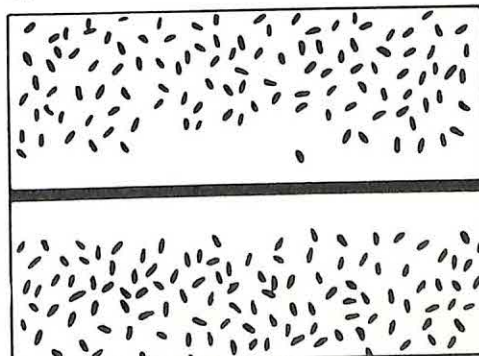
FIG. 2



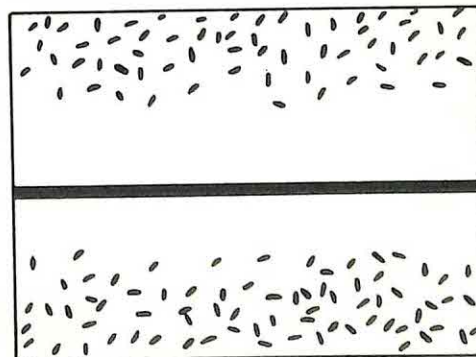
a



b



c



d

FIG. 3

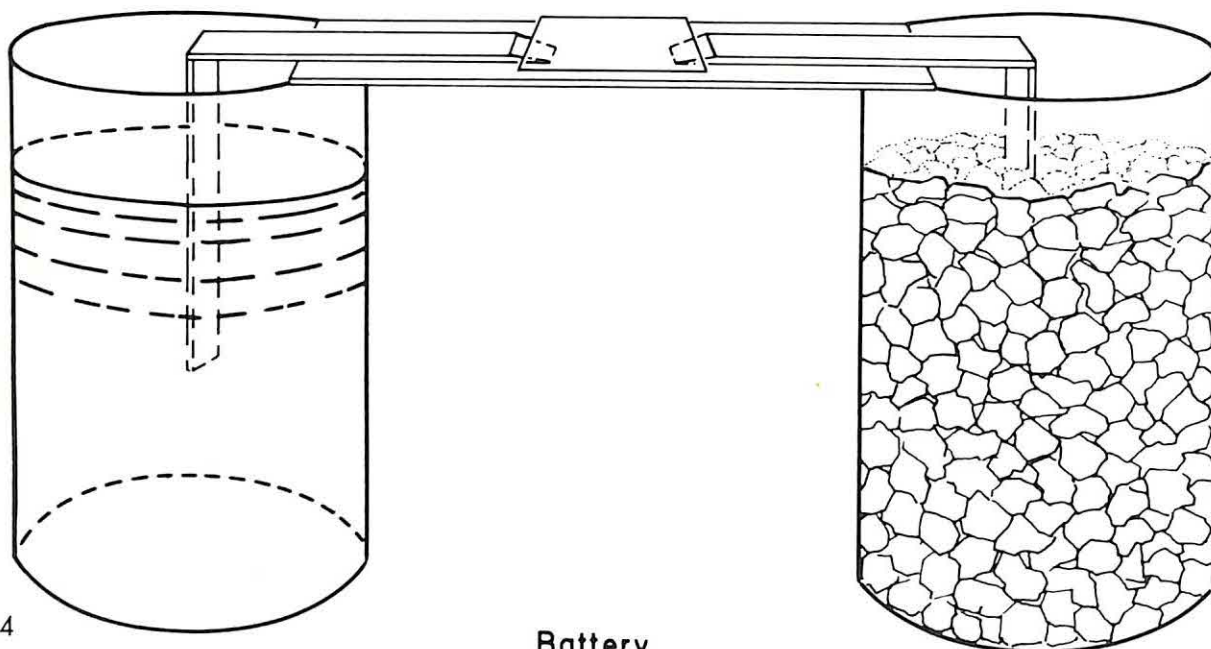


FIG. 4

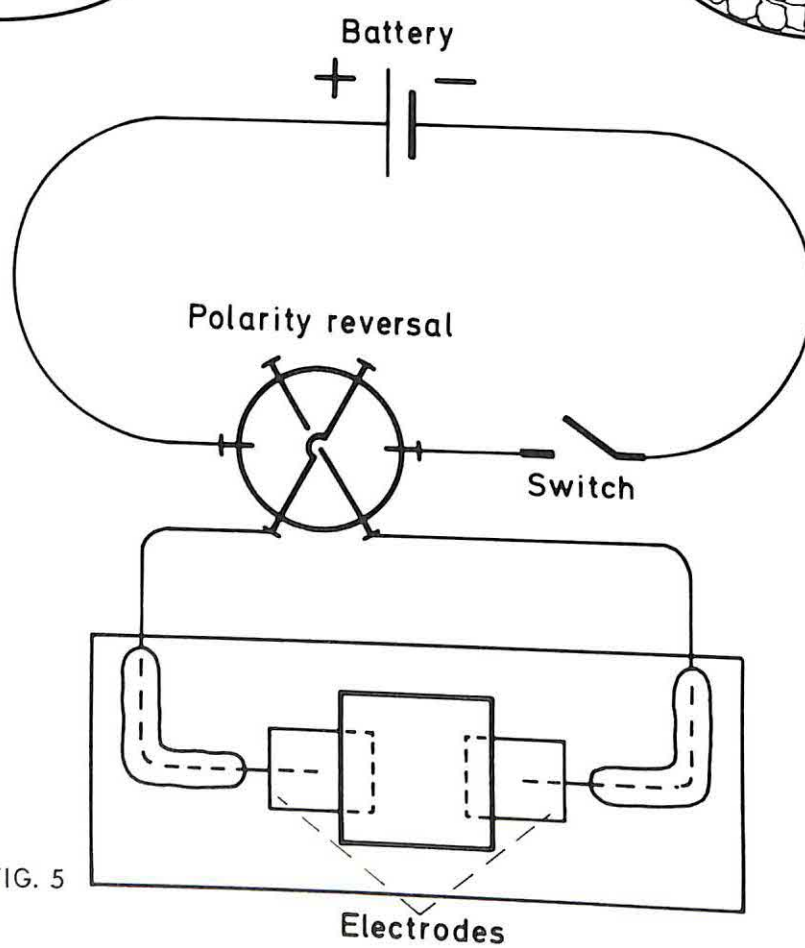


FIG. 5



FIG. 6

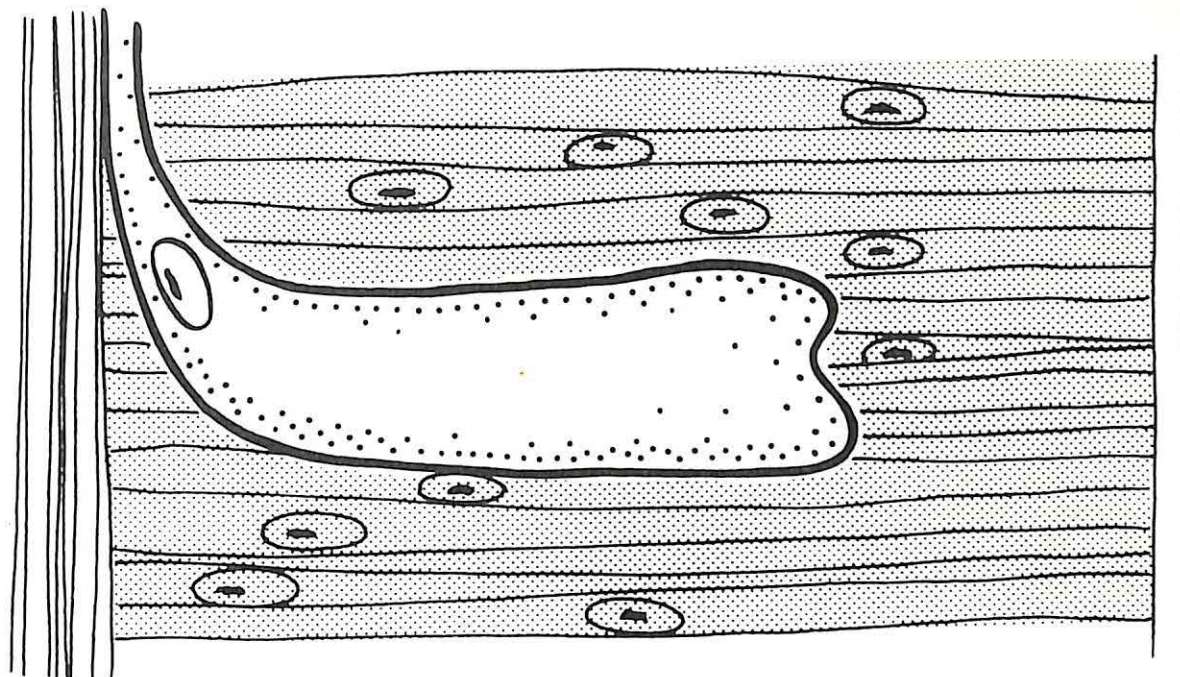


FIG. 7

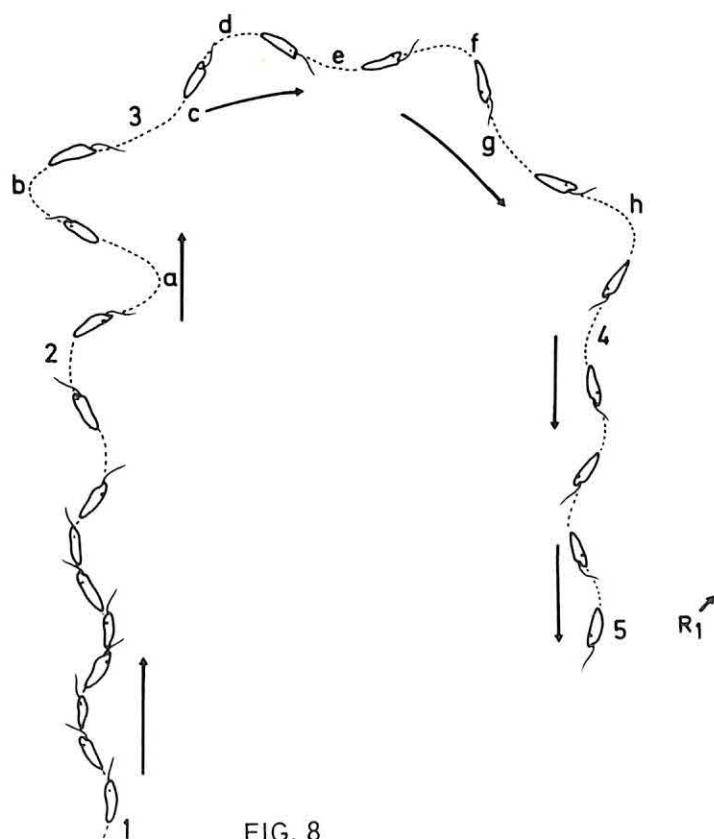


FIG. 8

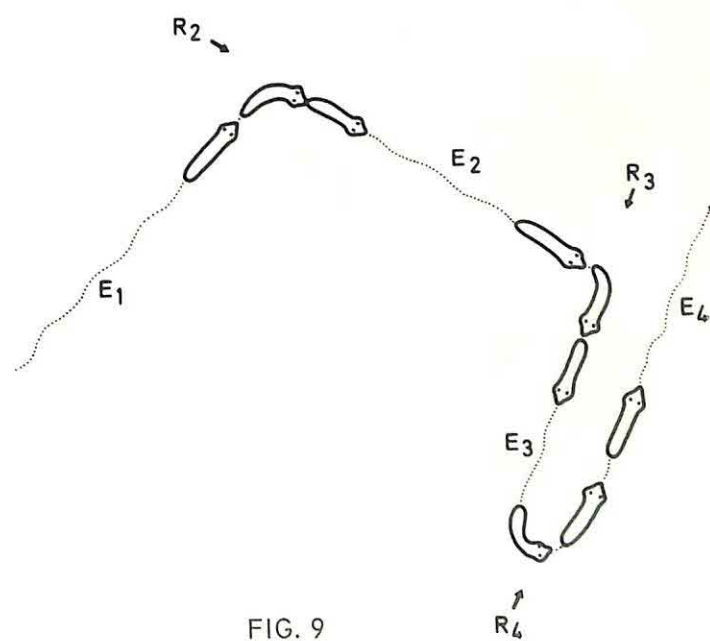


FIG. 9

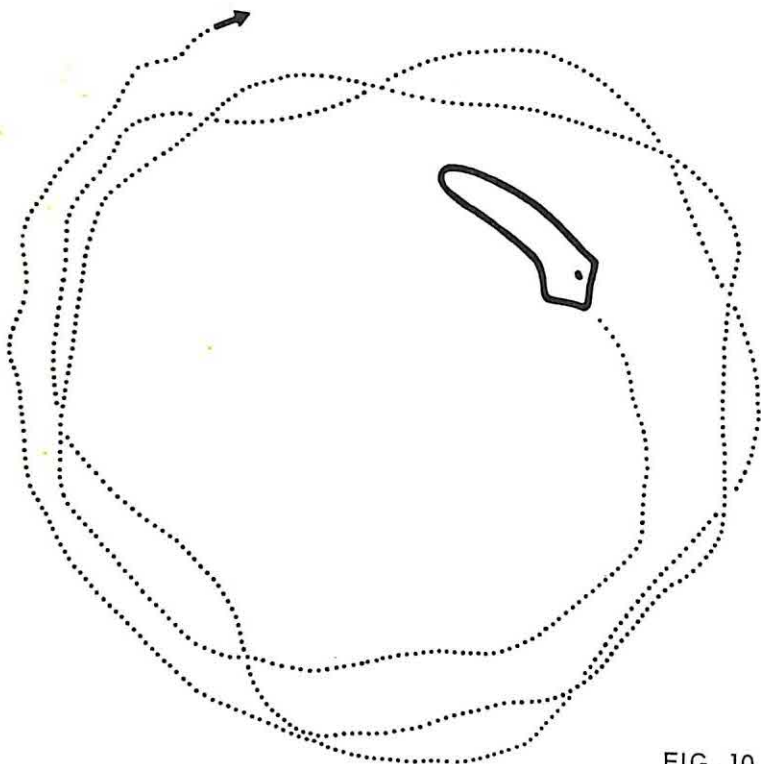
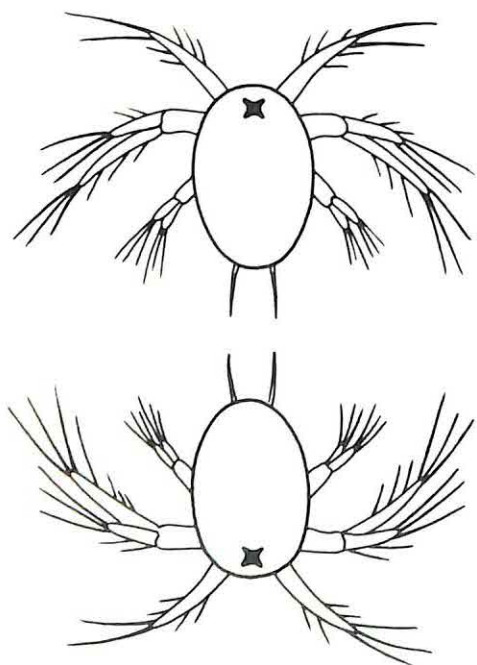
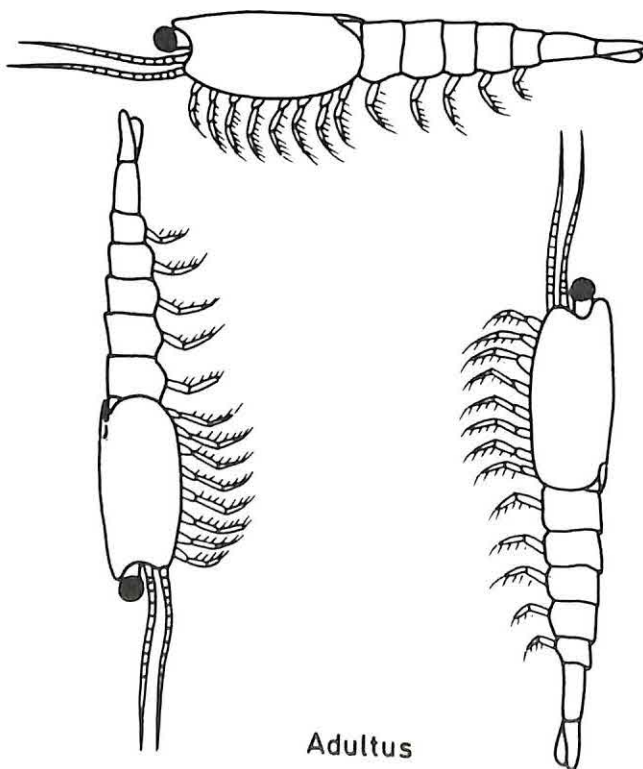


FIG. 10



Nauplius



Adultus

FIG. 11

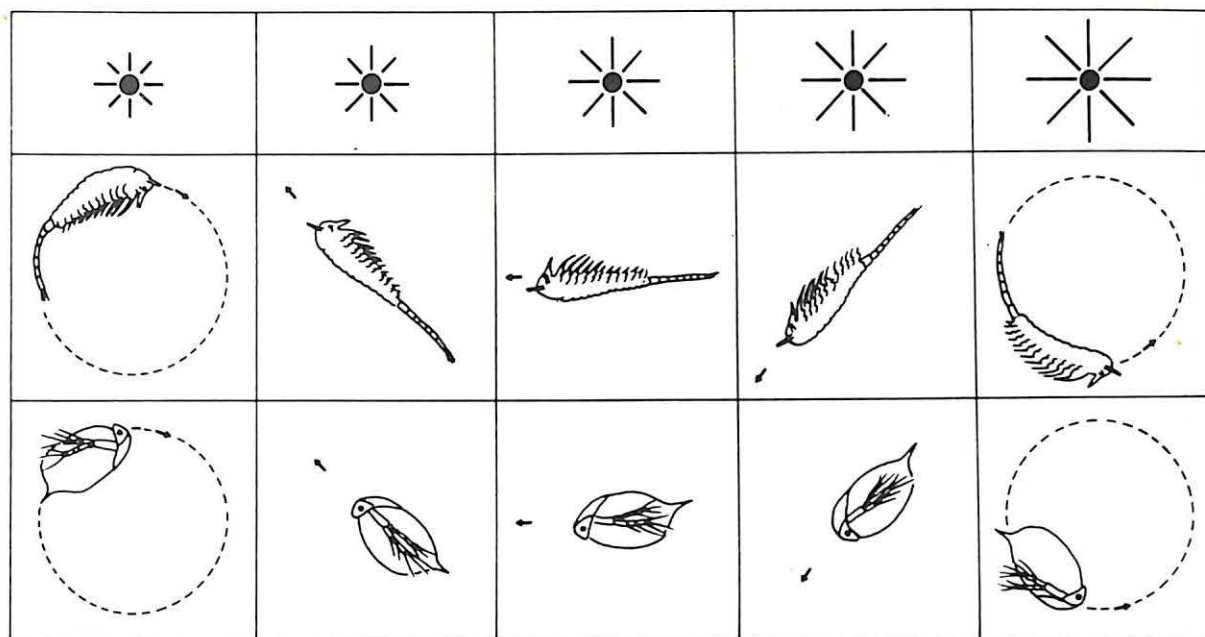


FIG. 12

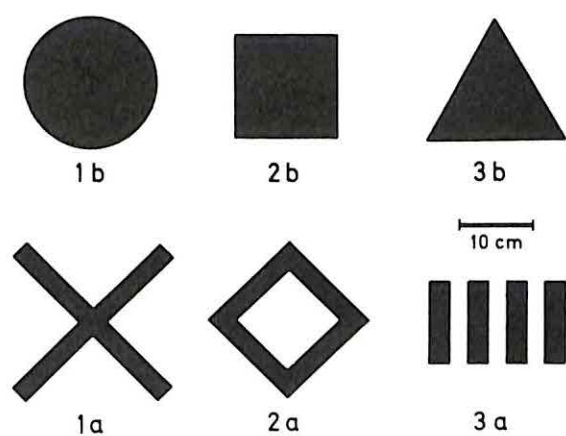


FIG. 13

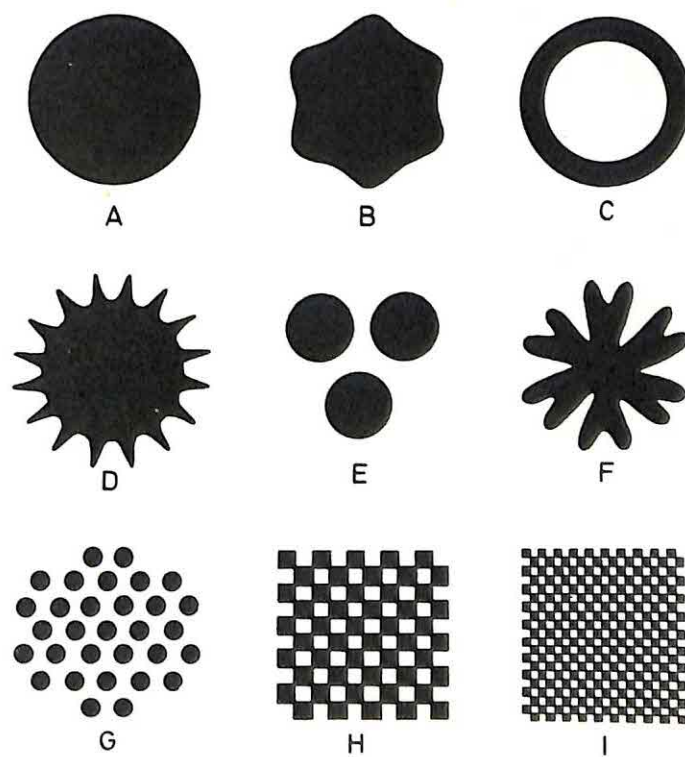


FIG. 14

$$\alpha_+ = 0^\circ$$

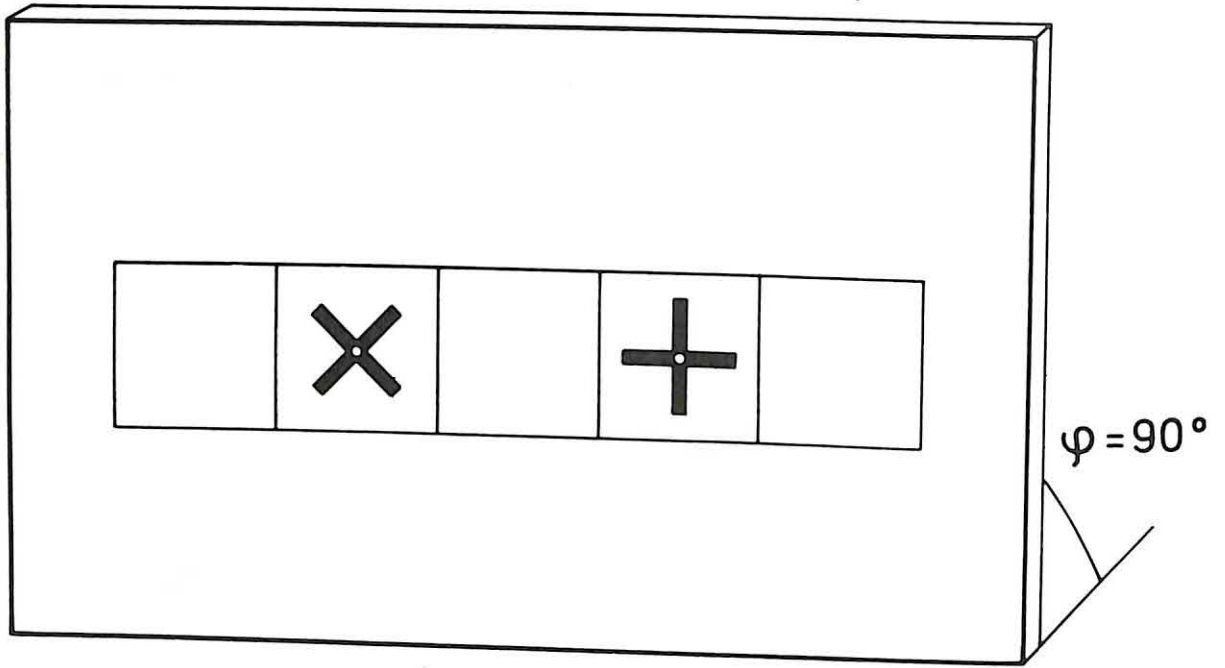


FIG. 15

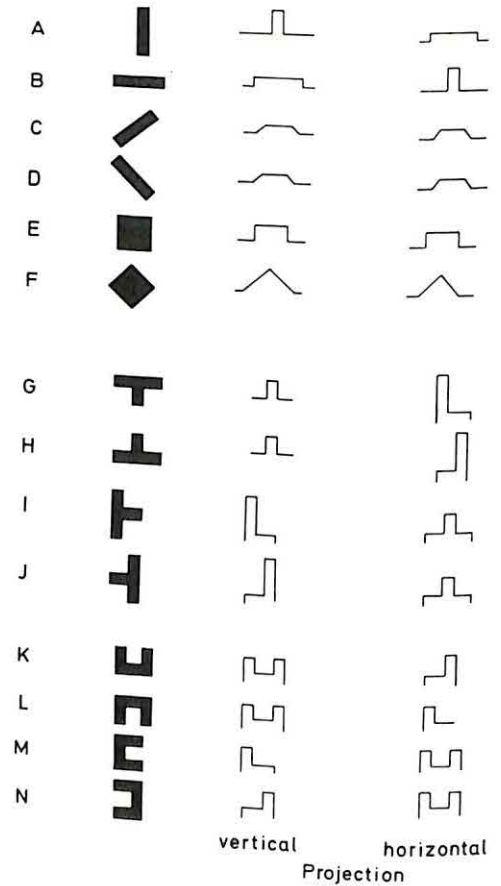
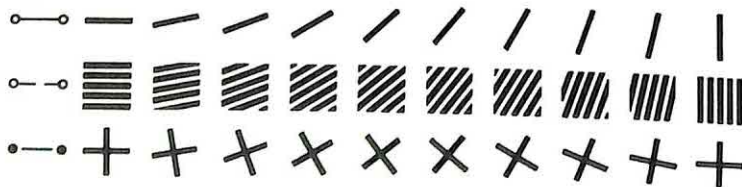
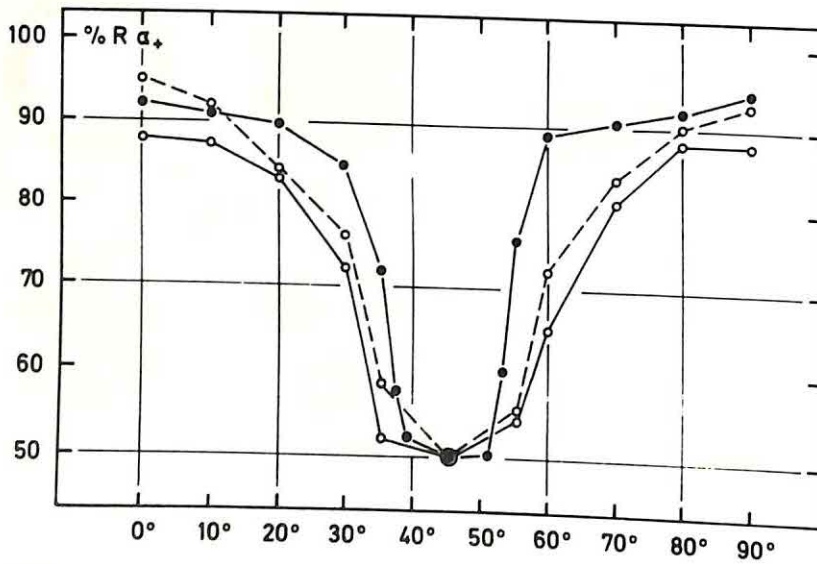


FIG. 16

FIG. 17

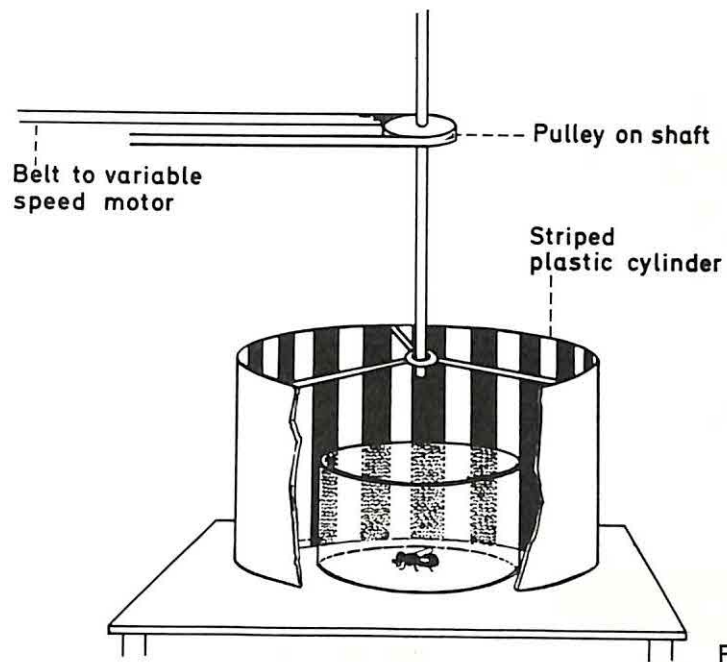


FIG. 18

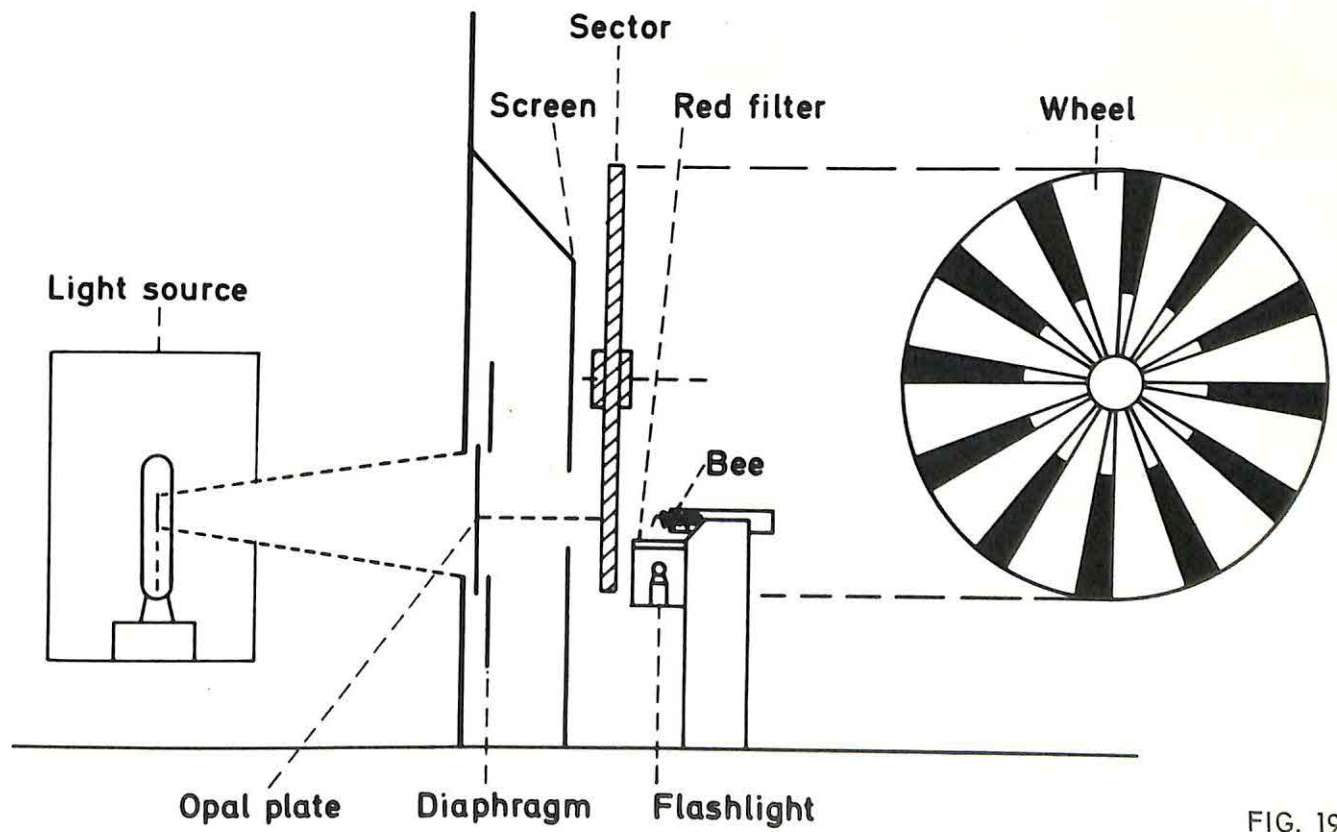


FIG. 19

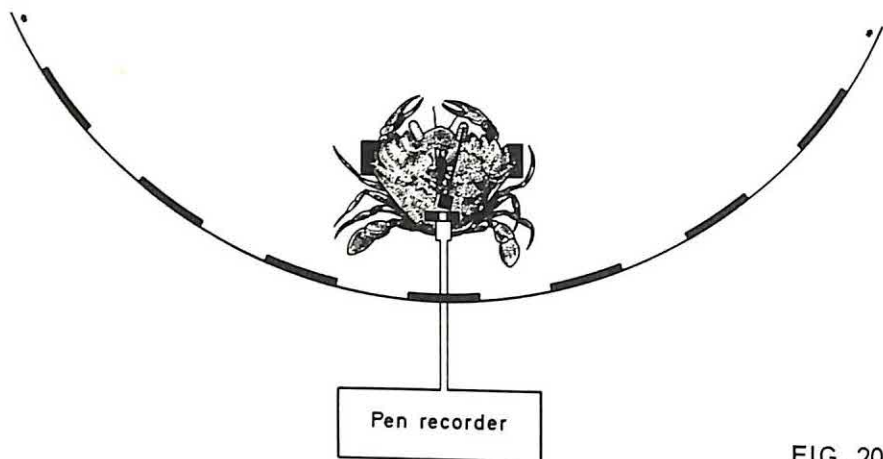


FIG. 20

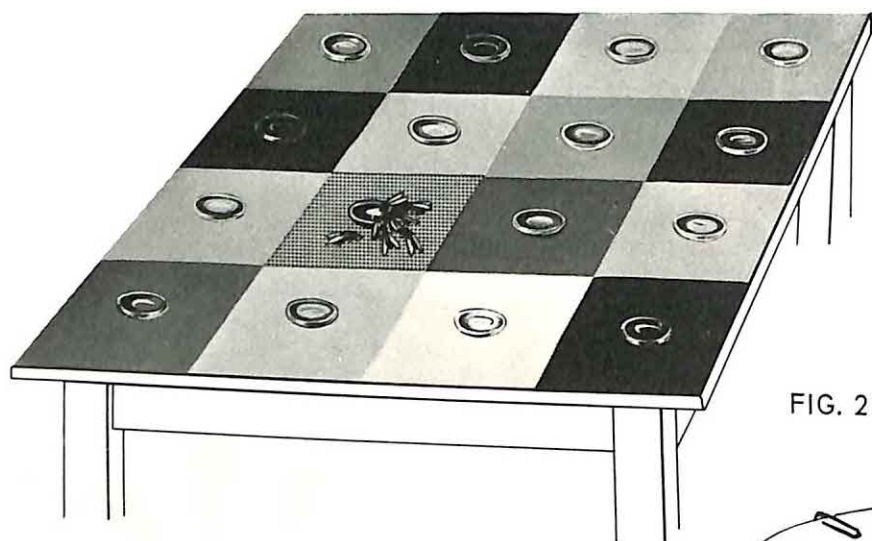


FIG. 21

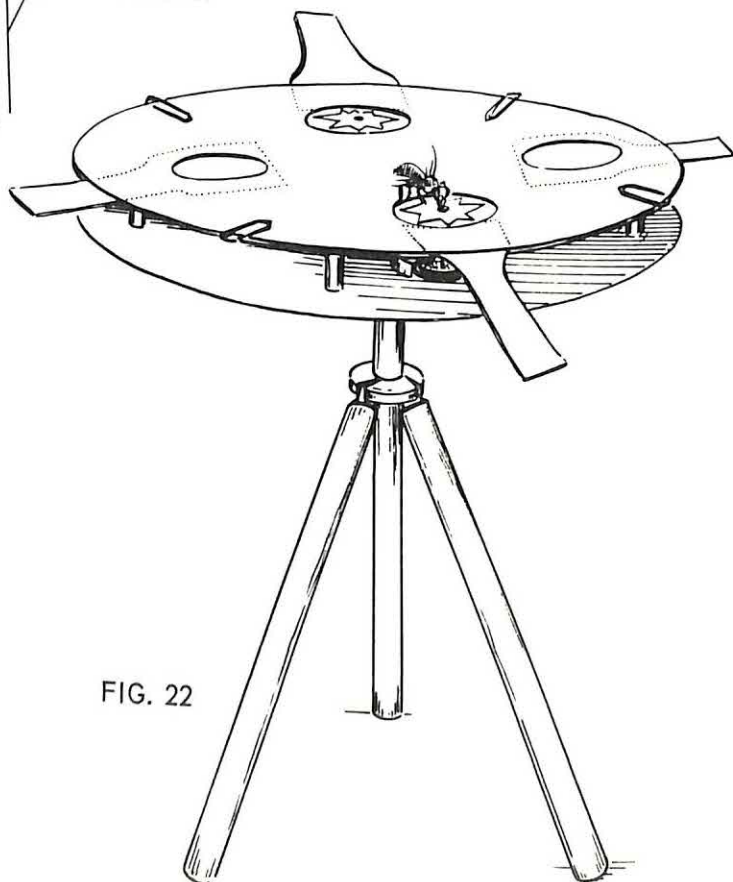


FIG. 22

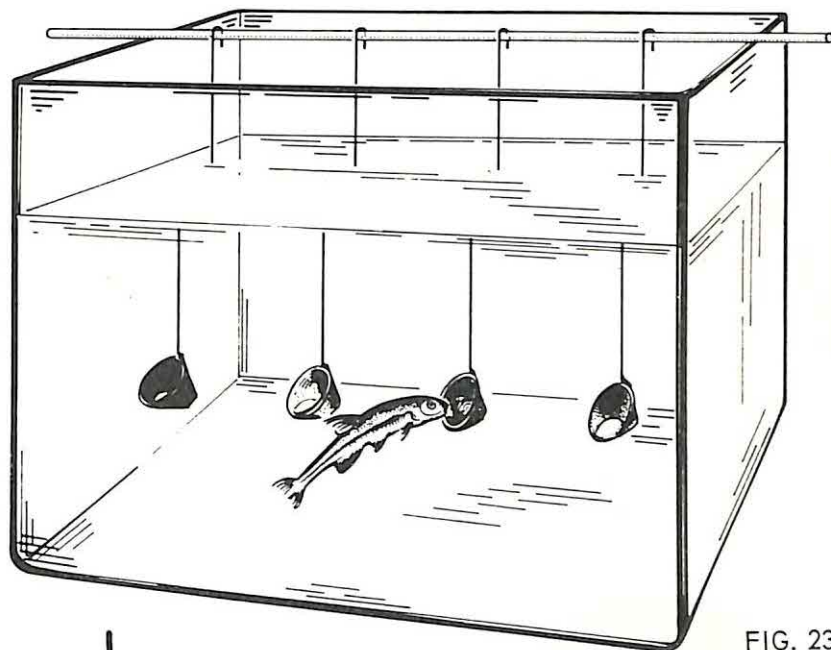


FIG. 23

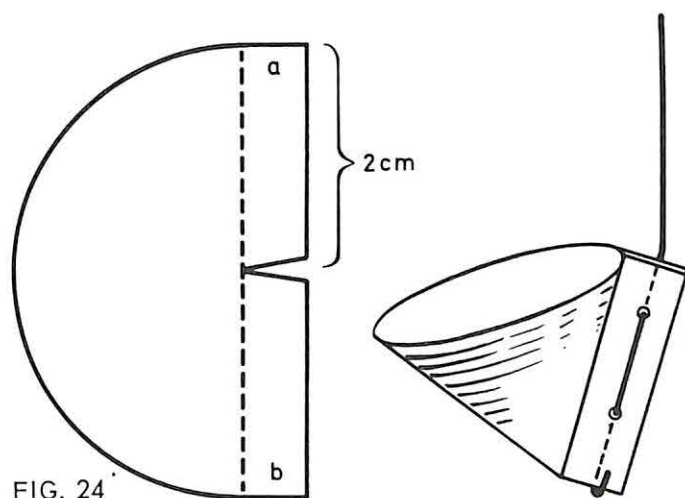


FIG. 24

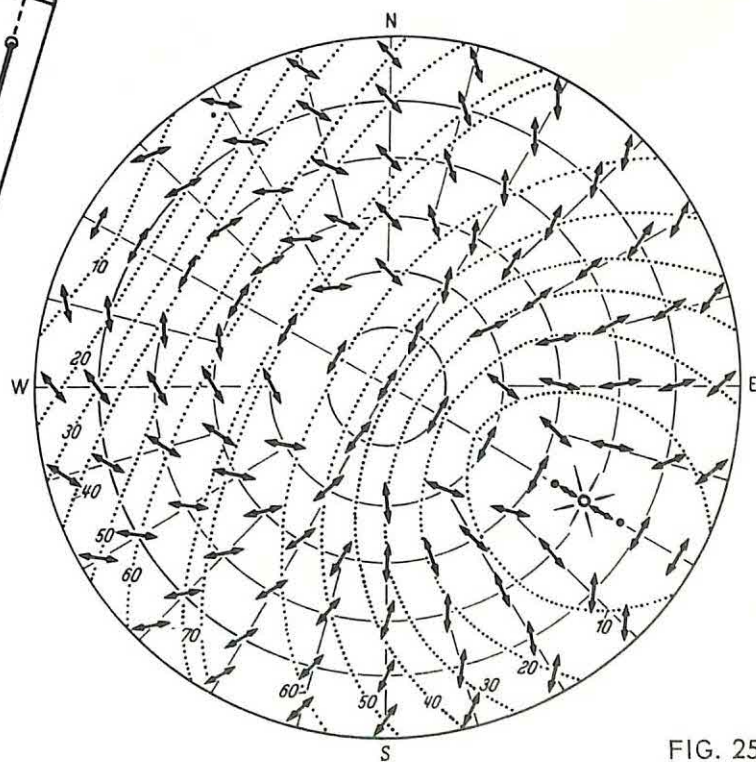


FIG. 25

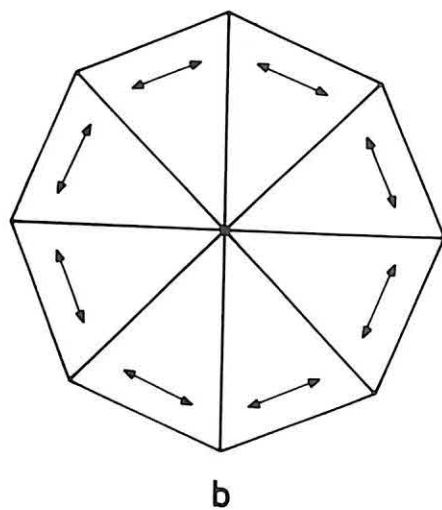
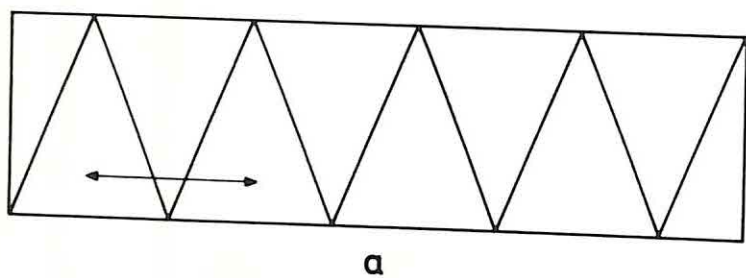


FIG. 26

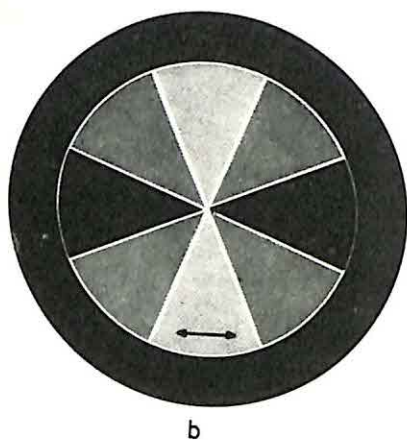
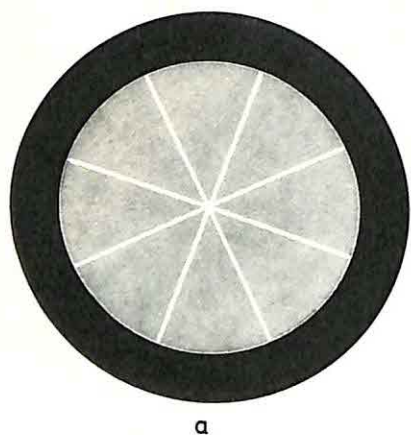


FIG. 27

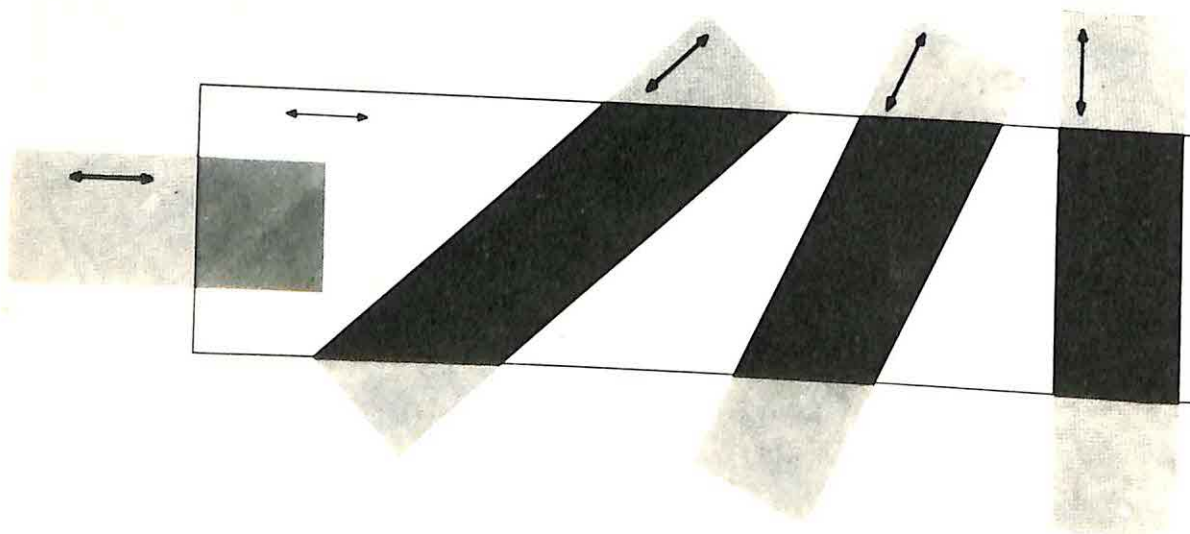
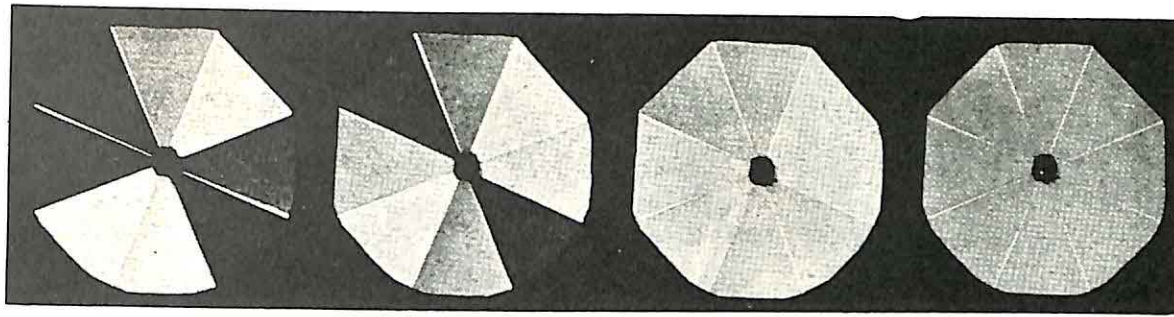


FIG. 28

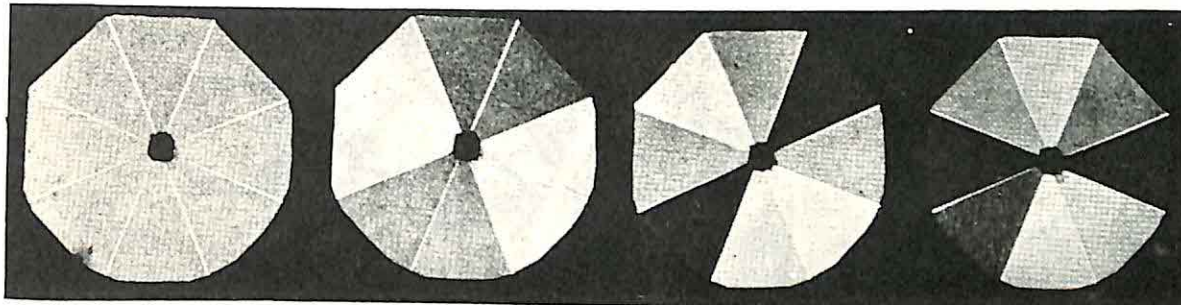


Nord

Nordost

Ost

Südost



Süd

Südwest

West

Nordwest

FIG. 29

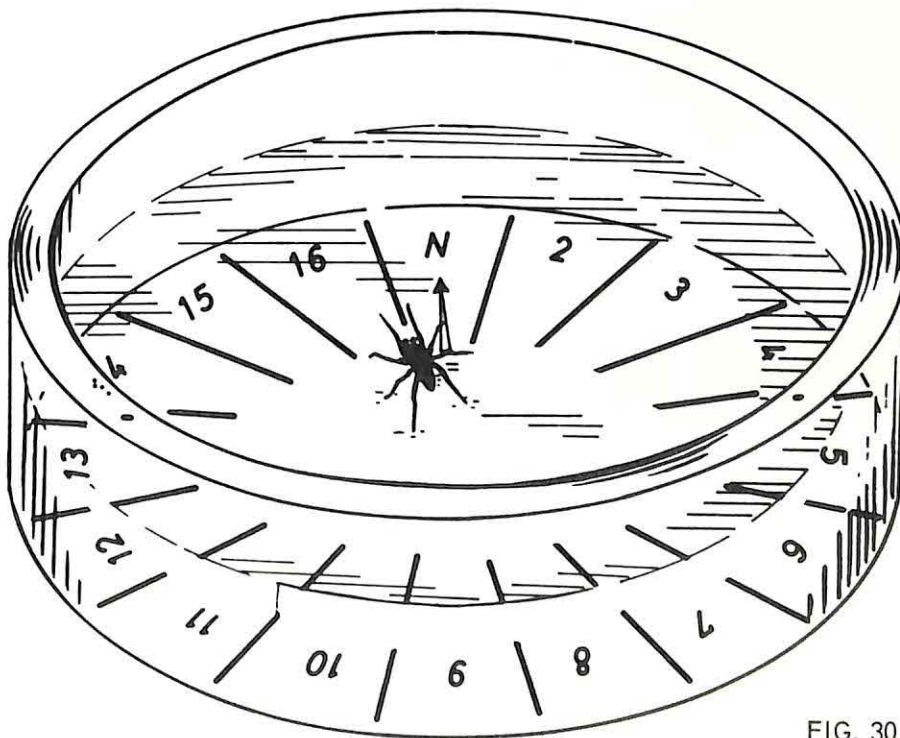


FIG. 30

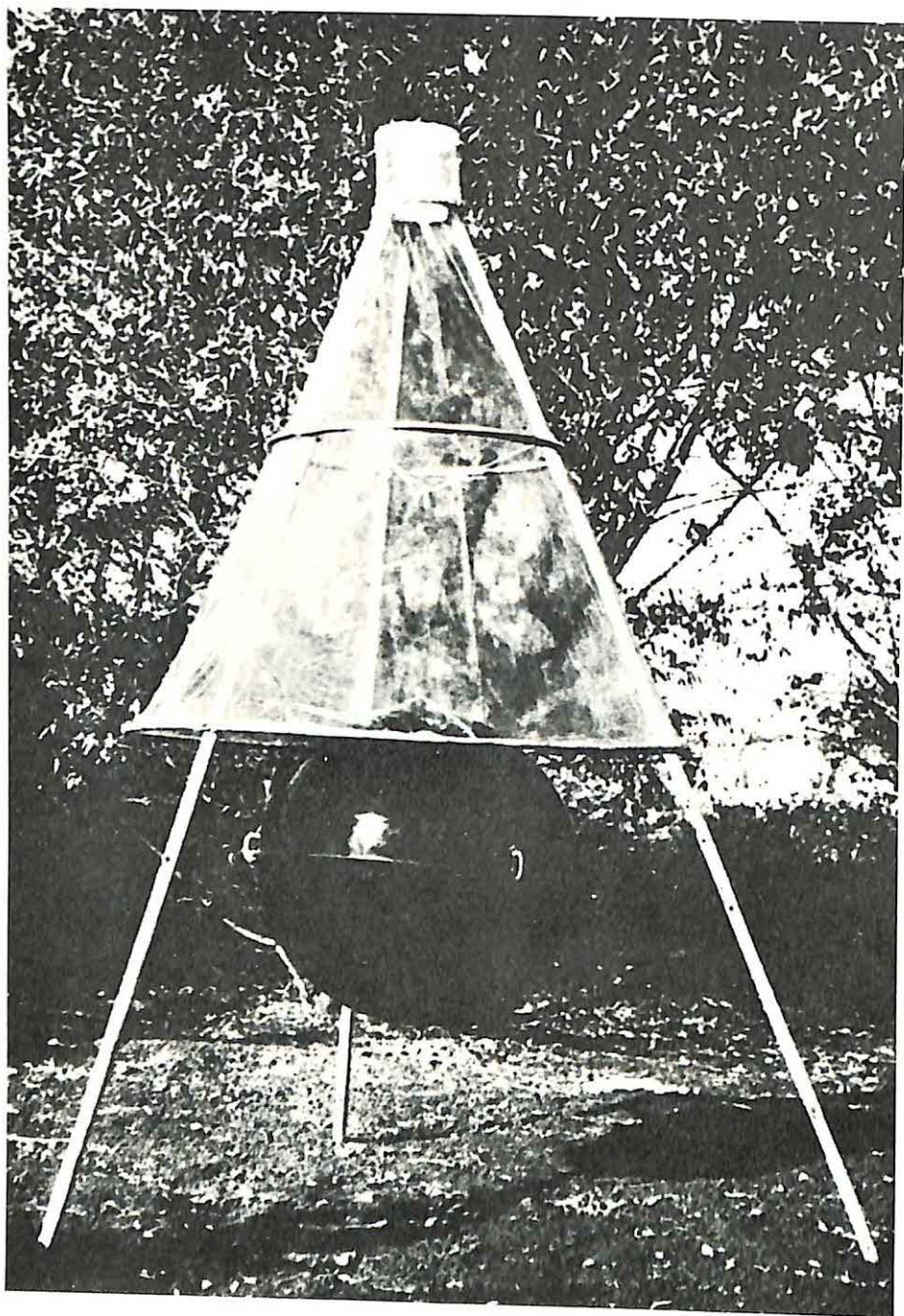


FIG. 31

Laboratory Exercises in Physiology and Behaviour

M. Lindauer

(Résumé)

Jusque vers 1950, le propos du Biologiste avait été de cataloguer, d'ordonner, de comparer les différents aspects du comportement des organismes vivants. L'époque est venue pour lui de se pencher sur la physiologie même de ce comportement.

A titre d'introduction, il est proposé à l'étudiant, un certain nombre d'exercices aisément réalisables :

- comportement de la Paramécie en fonction de variations du milieu ambiant (chimiotaxie, thermotaxie, galvanotaxie) ;

- réactions phototropiques de certains insectes, poissons, larves ou crustacés (phototaxie positive, négative ou transverse...) en relation avec la localisation, la nature, les déplacements ou l'intensité d'une source lumineuse donnée ;

- perception des formes chez les abeilles, des mouvements chez les papillons, des couleurs chez les poissons, de la révolution solaire chez les fourmies, pour ne citer que ces organismes de référence.

Ejercicios de laboratorio sobre fisiología y comportamiento

M. Lindauer

(Resumen)

Hasta 1950 aproximadamente, la función del biólogo consistía en catalogar, ordenar y comparar los diferentes aspectos del comportamiento de los seres vivos. Ha llegado ya el momento de que examinen la fisiología de ese comportamiento.

A título de introducción se proponen diversos ejercicios fácilmente realizables por el estudiante :

- comportamiento del paramecio en función de las variaciones del medio ambiente (quimiotaxia, termotaxia, galvanotaxia) ;

- reacciones fototrópicas de ciertos insectos, peces, larvas o crustáceos (fototaxia positiva, negativa o transversa, etc.) en relación con la localización, la naturaleza, el desplazamiento o la intensidad de una determinada fuente luminosa ;

- percepción de la forma en las abejas, de los movimientos en las mariposas, de los colores en los peces, de la revolución solar en las hormigas, por no citar más que esos organismos de referencia.

III. — EQUIPEMENT IMPROVISÉ POUR DISSECTIONS

(René VIGIN, Lycée, Fianarantsoa, Madagascar)

Ces suggestions voudraient orienter des collègues naturalistes arrivant dans un établissement (lycée, collège, C.E.G.) démunis de tout équipement de laboratoire pour dissection et désireux de réaliser quelques dissections en cours

d'année scolaire. Comment équiper rapidement les salles de travaux pratiques pour entreprendre dès que possible des dissections effectives, surtout si l'on dispose de peu de crédits? On ne peut toujours avoir recours au matériel spécialisé coûteux et pas toujours disponible assez rapidement. Il faut prévoir que l'équipement pour un groupe de T.P. (cuvettes et troussees complètes) revient de 50 à 70 F en métropole et il faut compter 8 à 12 groupes à équiper pour des séances de 24 élèves maximum.

A) Cuvettes à dissection.

Deux options sont à envisager suivant les ressources financières disponibles :

1^o Acheter des récipients du commerce, propres à servir de cuvettes à dissection. On peut citer : plats pyrex rectangulaires (320x180x50) qui sont incontestablement ce qu'il y a de plus pratique, mais relativement coûteux (7 F environ); plats pyrex ovales à rôtir; plats émaillés, en terre cuite (fragiles), en faïence (facile à nettoyer) ou en aluminium de forme rectangulaire ou ovale.

Le plateau émaillé 400x200x40 utilisé dans les hôpitaux (s'adresser à un service pharmaceutique) ou la cuvette photographique Kodak en matière plastique 300x400, ou le plateau de faïence blanche pour boucheries conviennent particulièrement bien.

2^o Plus économiquement, on peut faire fabriquer par des ateliers locaux des cuvettes rustiques à l'aide de plaques de fer-blanc (600x800) ou de plaques de tôle. Découper des plaques rectangulaires 300x400 dans de la tôle de récupération de carrosserie (qui s'oxyde moins que la tôle neuve et se découpe facilement en petites dimensions). Tracer un cadre rectangulaire à 50 mm des bords de la plaque; reporter deux centimètres de chaque côté des angles de la plaque; joindre les points ainsi obtenus aux angles du cadre intérieur et découper les segments ainsi délimités à la scie à métaux (fig. 1). Replier obliquement les bordures du cadre vers l'intérieur en prenant les côtés du cadre pour charnière. Souder au chalumeau les arêtes qui seront normalement jointives aux angles de la cuvette pour la rendre étanche. Les cuvettes obtenues sont légères, solides et tout à fait étanches. Une ou deux couches de peinture au minium ou à l'argent achèveront de protéger la cuvette contre l'oxydation.

B) Fonds de cuvette.

Les cuvettes du commerce possèdent un fond rectangulaire de liège ou de caoutchouc épais. Ces matériaux sont parfois difficiles à se procurer. On peut les remplacer par du bois tendre tel que le faux camphrier, en planchettes de 10 mm; le bois convient si les épingles s'y enfonce facilement; lester de barres ou de masses de plomb pour empêcher les plaques de flotter quand on emplit la cuvette d'eau.

Ce procédé habituel peut être remplacé par un autre plus commode et plus simple, que j'ai vu utiliser dans des laboratoires de recherche et que j'ai utilisé moi-même avec succès. Se procurer 2 kg de cire brute d'abeille et 1 kg de saindoux pour 10 cuvettes environ (de vieux cierges donnent une cire excellente utilisable sans mélange). Faire fondre le mélange au bain-marie; couler au fond de chaque cuvette chaude la cire fondue sur 10 à 15 mm d'épaisseur; laisser refroidir lentement. Quand le mélange est encore visqueux, on peut plonger obliquement dans la cire, à chaque angle, un petit anneau à rideau ou un cavalier dont on laisse sortir l'extrémité de la boucle (fig. 2 et fig. 3). Les avantages pratiques sont consi-



plaque de tôle (carrosserie p.e.)

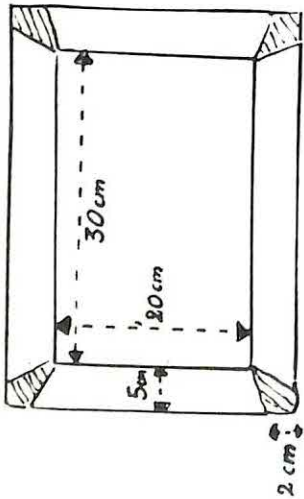
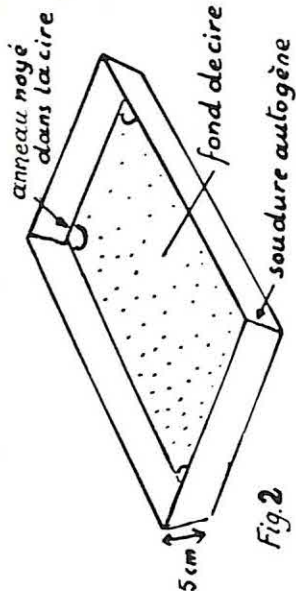
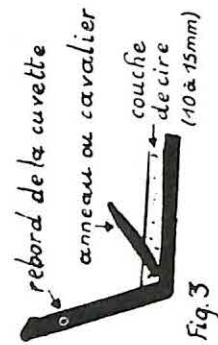


Fig. 1. (scier les parties hachurées)



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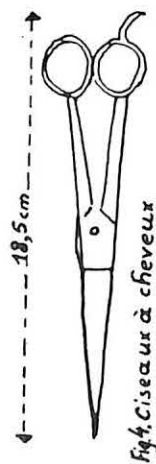


Fig. 4. Ciseaux à cheveux



Fig. 5. Spatule et gratte-angle



Fig. 6

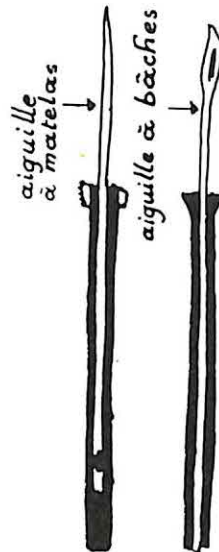


Fig. 7



Fig. 8

dérables par rapport au système habituel : lest rendu inutile ; les épingles s'enfoncent facilement dans la cuvette ; la cire n'abîme pas le morfil des scalpels ; les crochets latéraux permettent de fixer par les pattes à l'aide de fils nylon ou de ficelle un petit animal tétrapode pour en faciliter la dissection ; le nettoyage de la cuvette est facile et simplifié ; les coups de scalpels et d'épingles dans la cire ne sont pas irréparables comme dans le liège ; il suffit de faire refondre la cire pour obtenir une nouvelle surface aplanie.

C) Instruments de dissection.

On peut équiper soi-même le laboratoire de séries de 8 ou 12 instruments ou conseiller aux élèves de se procurer eux-mêmes les instruments suivants :

- grands ciseaux à cheveux à lames droite affilées (fig. 4), très pratiques pour beaucoup d'incisions (1,25 F le modèle ordinaire) ;

- petits ciseaux à broder, 9 cm, modèle Singer chromé (2,90 F pièce) ;

- spatule pointue à gratter les peaux sur les ongles, 13 cm (1,50 F pièce), pouvant servir facilement d'aiguille lancéolée ;

- gratte-ongles, 12 cm, servant de scalpels à lame courte (1,60 F pièce) ;

- pinces à épiler, acier nickelé à mors carré, longueur 8 cm (0,60 F pièce) ;

- brucelles d'horloger à bec pointu (divers modèles existent ; le modèle fig. 6 constitue un instrument de haute précision, assez difficile à se procurer).

Deux autres instruments peuvent être improvisés sans frais :

- une aiguille montée confectionnée à l'aide d'un tube vide plastique de crayon à bille et d'une aiguille à matelas dont on aplatit le chas d'un coup de marteau ; une aiguille à bêche permet d'obtenir une sorte d'aiguille lancéolée (fig. 7) ;

- une pince faite à l'aide d'un morceau de feuillard à cercler les caisses (le feuillard inox est évidemment le meilleur).

Ces instruments sont peu solides mais peuvent être remplacés après un certain usage.

Pour les scalpels à longue lame, il est difficile de se passer des modèles commerciaux. On peut cependant tenter de souder des lames de canif en acier trempé au chalumeau sur des manches découpés dans de la tôle épaisse ou sur de grosses tiges cylindriques de métal. Eventuellement, de petits élèves pourront se contenter de petits canifs à lames très bien affûtées.

Un tel équipement aussi économique (5 à 15 F environ par groupe d'élèves) doit être à la portée d'établissements démunis ou pris en charge par les élèves eux-mêmes, car l'acquisition ou la confection, au prix d'un petit effort de « bricolage », d'un tel matériel doit passer en priorité avant l'achat de manuels largement aussi coûteux et qui ne peuvent jamais remplacer une dissection d'élève. Toutes les dissections simples (Vertébrés, Crustacés, Mollusques) peuvent être très bien réussies. Pour des dissections plus fines, la cire permet d'utiliser de petits rapiers rectangulaires 200x150x35 en verre, très commode pour disséquer de petits animaux sous la loupe ou la loupe binoculaire (Blatte, Criquet, chenille, Sangsue, alevin, têtard ou Lézard) avec des élèves de première M'.

Equipo improvisado para disecciones

R. Vigin
(Resumen)

Se formulan ingeniosas sugerencias para equipar de un modo rápido y económico las salas trabajos prácticos para hacer disecciones. Las costosas cubetas pueden sustituirse por diversos recipientes de uso corriente o incluso fabricarse de nuevo (para lo cual se dan indicaciones prácticas detalladas). Los fondos de las cubetas pueden hacerse con madera blanda o mejor con mezclas de cera bruta de abejas y de manteca de cerdo. La mayor parte de los instrumentos de disección pueden también sustituirse por objetos de uso corriente, tales como tijeras de costura, pinzas de depilación, limas para las uñas, etc., o fabricarse con poco gasto. La economía así realizada permite reducir el precio de costo medio de 60 F por grupo a 10 F y poner así al alcance de los establecimientos con pocos recursos las disecciones que son todavía más indispensables que los libros de texto.

Improvised dissecting equipment

R. Vigin
(Summary)

Ingenious suggestions are made for equipping school laboratories rapidly and at low cost for dissection work. A variety of containers in common use, or made out of any handy material, can be substituted for the normally expensive trays; specific practical advice is given. The flat bottom of the tray may be made from soft-wood or, better still, from a composition of untreated beeswax and lard. It is also possible to replace most dissecting instruments by every-day objects such as embroidery scissors, eye-brow tweezers, and orange-sticks (manicure sticks), or by other such equipment devised at little cost. As a result the average cost price for each group can be reduced from 60 to 10 F. This makes it possible for poorer schools to do dissection work, which is even more essential than text-books.

USING MODELS IN TEACHING HIGH SCHOOL BIOLOGY

Kozo Imahori

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The improved curriculum PSSC has been influenced in many ways to school sciences of the world, including, of course, Japan. Actually "Kagaku-Kyoiku no Gendaika" - which means the improvement of science education - is the most familiar topics in the Japanese educational circles.

Since high school biology in Japan is not an unusual case of the improvement, many reformed textbooks* which are mainly influenced by BSCS textbooks were published and used during these several years. Many new themes concerning molecular biology have appeared in these books, though very few textbooks which were published during nineteen-fifties mentioned about DNA, ATP, TCA cycle or even Calvin cycle.

To teach biology in molecular level, many difficulties are expected to be met with. First of all, almost all of the high school teachers have to be retrained to teach modern biology. Lucky enough for these teachers is that Science Education Center System which is found in great part of prefectures in Japan is now carrying out rehabilitation programs especially during summer holidays. More serious difficulties are, however, found at the students' situation especially by the Japanese special educational system. High school biology in this country is designated by the Ministry of Education to teach at 10th grade only, while chemistry and physics must be taught at 11th and 12th grades, and also, almost all students are required compulsory to take 5 units of Physics, 4 units of chemistry, 4 units of biology and 2 units of geology in the senior high school sciences course, but no subjects are left to choose. This system suggests that all students at 10th grade are destined to study molecular biology without any training for chemistry or physics. Their scientific informations are only acquired as a subject of general science at their junior high school. From the viewpoint of their scientific backgrounds, it seems almost meaningless to teach them the process of TCA cycle, applying so many names of organic substances such as succinic acid, citric acid and oxaloacetic acid. It is also absurd to teach them the process of electron transport system using names such as NAD, FAD or cytochromes. The importance is to teach them how ATP is produced theoretically as the energy substance. The problem is not to learn chemical process in the sense of terminology but to inquire into the ultimate truth of the living process.

* Textbooks in this country are controlled by Curricula Syllabus which is issued by Japanese Government.

To make hypothesis and then demonstrate to support it is one of the process of scientific enquiry. This process is usually the most successful way to learn science though it is not almighty. As far as concerning TCA cycle and electron transport system, it is very hard to prove the process through experiments in high school level, but, on the other hand, these problems are quite worthwhile for students to know the ingenious living process through these examples.

In order to overcome this difficulty, using model is a considerable way. BSCS had already pointed out the importance of using model, but very few models - such as muscle constraction - were shown in those three versions. AAAS program might be the first project which emphasized the using model, though the project is now only for elementary school level.

As far as high school biology concerns Nuffield Project is most prominently characterized by using models. Fig. 1 shows examples cited from the Nuffield Biology. The models used in this projects is, however, extends mainly in experimental process (fig.1), kind of model which is used to explain principles only is also found as shown in fig.1b. Examples introduced in the following part are models of the latter kind.

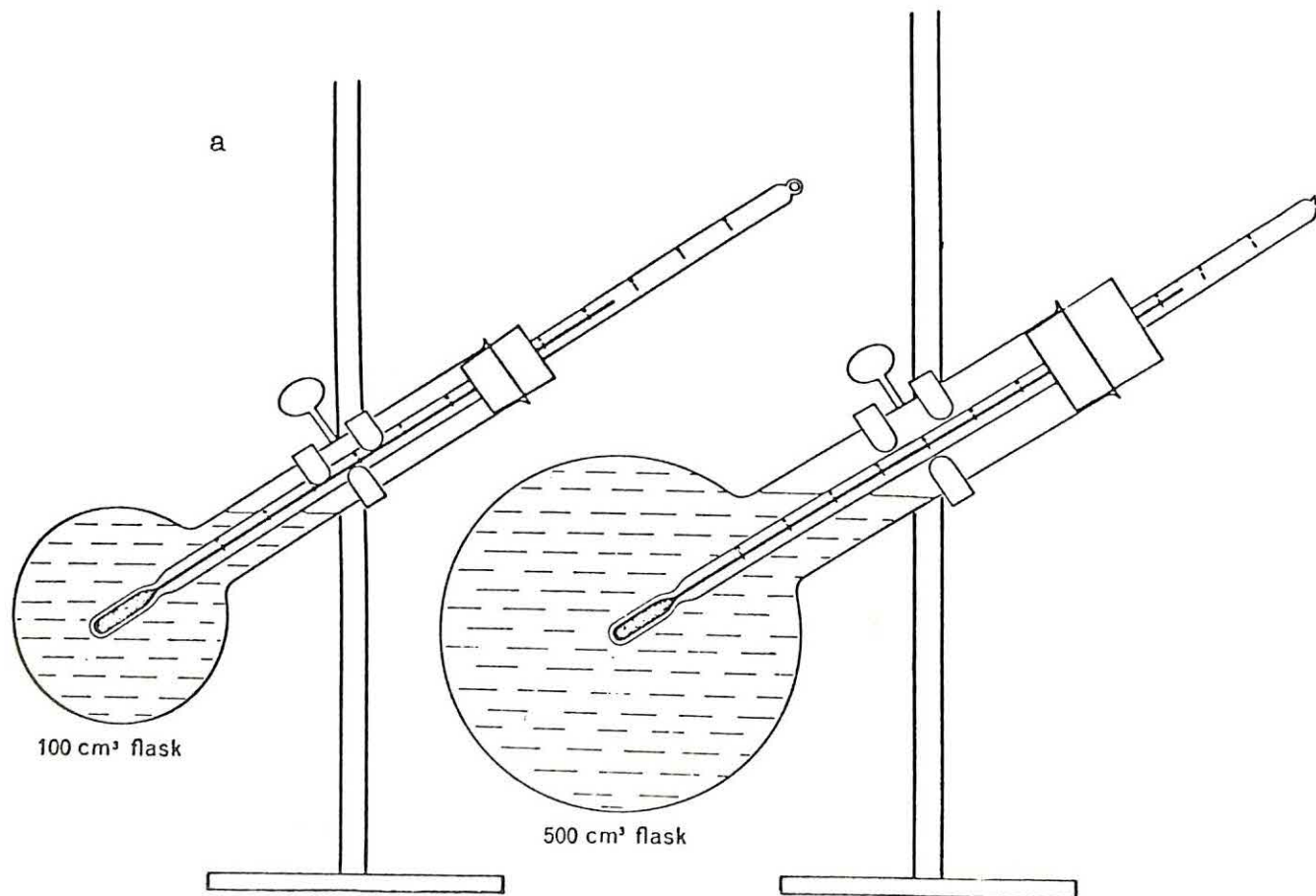


Fig. 1.- Models appeared in the Nuffield Biology.
a. A basic model of physical biology to find out the relationship between heat capacity and body size.
from vol. 2, p.87.

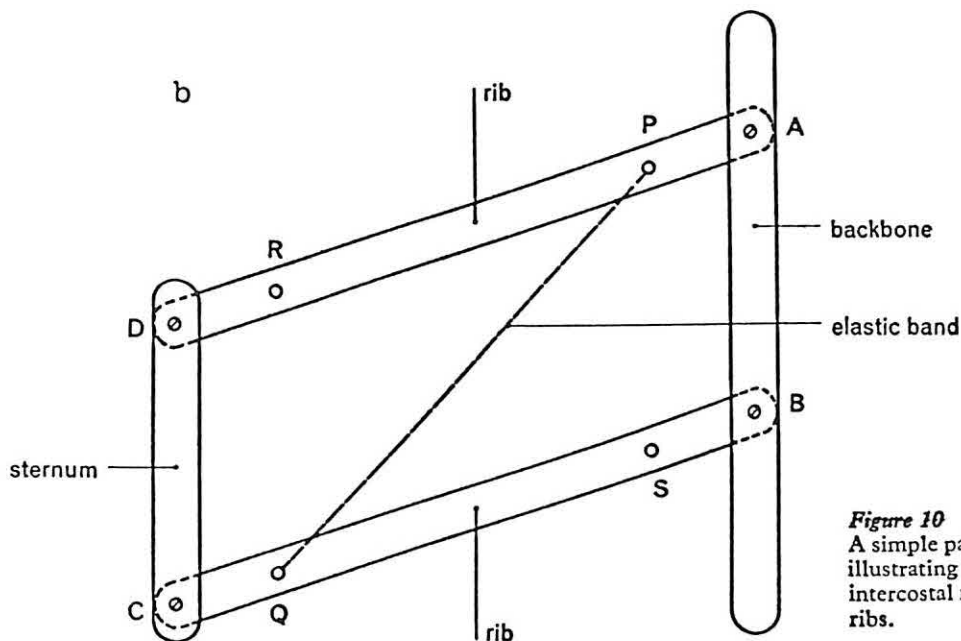


Figure 10
A simple parallelogram model illustrating the possible action of the intercostal muscles in moving the ribs.

b. A basic model of physical biology to find out the relationship between heat capacity and body size.
(from vol. 3, p.17).

1) Metabolic cycles and looplines.

The principle of TCA cycle is understandable easily but with much interest by comparing it with loopline bus. In this case the bus is comparable with oxaloacetic acid. The bus starts with passengers (acetic acid) on loopline (pathway of TCA cycle) which has several busstops (citric acid, keto-glutaric acid, succinic acid, etc.) passengers buy tickets (H_2) before they (CO_2) leave the bus.

Ornithine cycle is another suitable example of using model. As shown in fig. 2, a truck is compared with ornithine, which carries crates of NH_3 and CO_2 but finally unloads urea [$CO(NH_2)_2$].

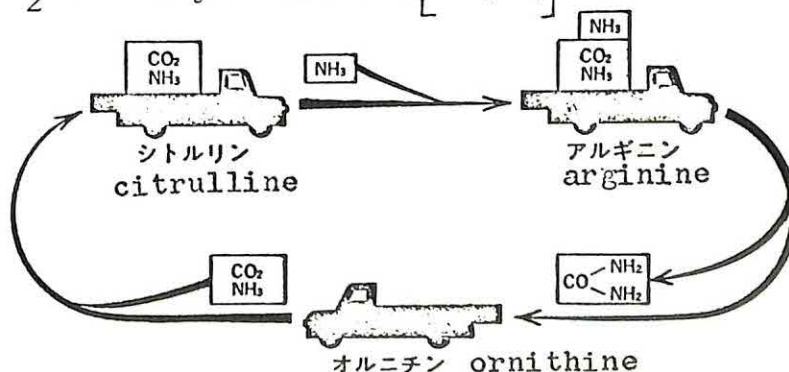


Fig.2.- A model explaining ornithine cycle(from High School Biology, ed. K.Inahori).

2) Two models of bioenergetics.

The process of energy production, energy preservation and energy consumption is easily understandable through this simple but familiar samples. Workmen are paid in Currents (ATP) by their labor (respiration) and go a bank for saving (creatine phosphate).

Then they draw their money in currents (ATP) from the bank and spend money (for buying goods muscle construction). Fig. 3 shows this process in model.

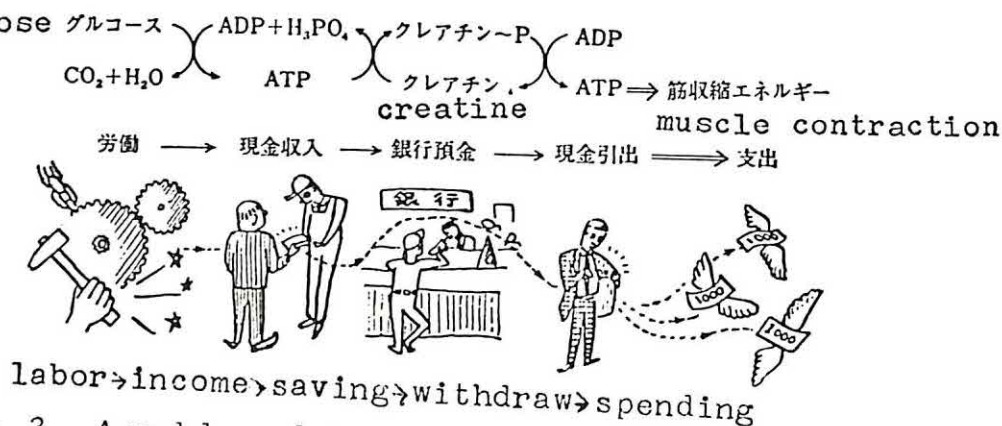


Fig. 3.- A model, explaining energy transformation. (from Biology in New System, ed. K. Imahori).

Electron transport system is a complicated, rather difficult to learn but very interesting and important phenomenon found in the bioenergetics. No explanation is made in the blue version of BSCS textbooks, but a model is used in the yellow version (p.134). The importance of this phenomenon is to explain how the molecules of ATP are produced from H and hydrogen acceptors such as O.

The only and best way to make this process understandable for high school students is using model as seen in the yellow version.

The following figure (fig. 4) is one of an ideal model of the discussing process. Water (H₂) is running down to an electric powerhouse, where a generator (electron transport system) being set on motion by water to generate electricity (ATP). Water is then drain out into river (H₂O) through drainpipe (O₂).

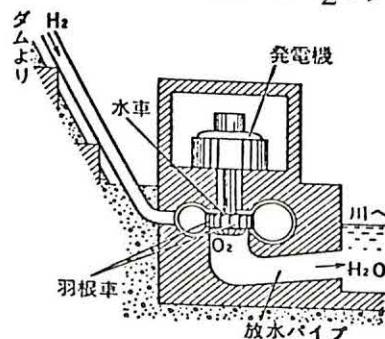


Fig.4.- A model explaining ATP production by electron transport system which is compared with an electric powerhouse. (from High School Biology, ed. K. Imahori).

Anyway using models is one of the most practical, ideal way in teaching biology as well as in researching sciences.

Using Models in Teaching High School Biology

Kozo Imahori

(Résumé)

Dans la réforme éducative avec les progrès remarquables des sciences biologiques, il est très important que nous essayons de faire comprendre les phénomènes vitaux aux étudiants par l'intermédiaire des modèles appropriés qui manifestent les principes fondamentaux de la vie. A propos de ces modèles, nous présentons ici plusieurs exemples que nous avons mis au point à l'aide d'études méthodiques et d'expériences pratiques.

Empleo de modelos para la enseñanza de la biología en el nivel secundario

Kozo Imahori

(Resumen)

En la reforma de la enseñanza y debido a los notables progresos de las ciencias biológicas, es muy importante que tratemos de hacer comprender los fenómenos vitales a los estudiantes por intermedio de modelos apropiados que manifiesten los principios fundamentales de la vida. A propósito de esos modelos presentamos aquí varios ejemplos que hemos preparado mediante estudios metódicos y experimentos prácticos.

UN IMPORTANT FACTEUR DE L'ETUDE DE LA BIOLOGIE : LA RECOLTE D'ECHANTILLONS SUR LE TERRAIN

par H.H. Joomaye

Directeur du Groupe d'étude permanent Projet-Pilote de l'Unesco
pour l'enseignement de la biologie en Afrique

Royal College, Port-Louis (Ile Maurice)

L'étude de la Biologie, science de la vie, ne peut se cantonner à l'enceinte du laboratoire, et se limiter à la dissection de spécimens préservés, ainsi qu'à la préparation et à la coloration de coupes destinées à être reproduites sous forme de dessins. L'étude de l'organisme dans son milieu naturel en lutte avec les autres organismes vivants, soumis à l'action favorable ou non du sol, de la température, de la lumière, de la sécheresse et de l'humidité, est une des branches les plus négligées de la biologie. On admet cependant qu'une étude complète ne peut se faire par de simples observations de l'organisme dans son milieu naturel. Les travaux de laboratoire complètent les recherches sur le terrain.

La récolte des spécimens n'est qu'un seul aspect des travaux sur le terrain qui sont définis ici comme travaux hors laboratoire. Une grande quantité de matériel est récoltée durant les excursions écologiques. La meilleure réponse à la question "où peut-on trouver du matériel" est "que cherchez-vous"? La mer, les eaux intérieures, les collines, les bois fournissent tous du matériel en abondance, cependant ce ne sont pas les seules sources, il y en a d'autres.

Il est impressionnant, je suppose, d'avoir un petit musée contenant un choix de matériel, mais à quoi peut servir de conserver des spécimens desséchés tombant en morceaux ou de conserver des échantillons décolorés, s'ils peuvent être obtenus frais d'un jardin public, de ceux d'une école ou d'un maraîcher ; il suffit de planifier le programme de travail de façon que les leçons soient données au bon moment, c'est-à-dire à l'époque où on peut obtenir des spécimens frais. Toutefois cela n'est pas aussi facile dans le cas d'organismes microscopiques ou de matériel nécessaire à l'étude de la morphologie comparative des plantes.

Réunir une collection nécessite une planification minutieuse, mais, dans la nature, on peut si difficilement prévoir et le biologiste doit souvent improviser lorsqu'il doit faire face à une situation imprévue, ou bien il lui faut transporter un imposant chargement d'outils.

Il est possible d'obtenir des passe-thé et des filets en nylon de dimensions variées. Le collectionneur a besoin de sacs en plastique de tailles différentes, de bonnes loupes, de pièges, de seaux, de thermomètres, solution d'acide dilué, d'une trousse complète pour analyser le sol, de papiers réagissant au pH pour déterminer l'acidité du sol. On doit rappeler qu'il faut un équipement beaucoup plus important pour les recherches écologiques. On ne s'occupe ici que de la collection. Des échantillons d'eau doivent être pris afin d'en déterminer, par examen de laboratoire, la salinité, la densité, et la teneur en oxygène. Le ramasseur doit noter la localité, la saison, la date et l'heure de la collecte. Était-ce marée basse ou marée haute ? L'eau provient-elle d'une mare, d'un ruisseau au cours lent ou d'une rivière dévalant de la colline ? Il ne faut pas se fier à la mémoire. Toutes ces données sont importantes au moment où on effectue des comparaisons. Il est essentiel de faire une liste du matériel qui n'a pas été récolté. Ceci est nécessaire afin d'expliquer(i) une chaîne de nourriture, s'il en existe une et (ii) la densité des différentes populations.

Les crevasses et les surfaces de roches fournissent un grand choix d'organismes. Les eaux saumâtres de l'intérieur ont leur propre flore et faune. Ici aussi, on devrait procéder aux mêmes observations.

Les saisons ont-elles un effet sur toutes les plantes ? Dans certains pays les pois de senteur (*Lathyrus odoratus*) fleurissent d'octobre à fin novembre, certainement pas en mars. Ce phénomène est-il commun à toutes les plantes ? et les fougères ? Il faudrait aussi ramasser du matériel sur différentes plages. Des morceaux de bois en pourriture trouvés sur la plage sont des univers en eux-mêmes. Il faudrait organiser des excursions pour ramasser du matériel pris dans les ruisseaux coulant près des usines. Souvent les eaux sont polluées par les déchets des usines qui affectent ainsi les populations vivantes. A l'Ile Maurice, la population des ruisseaux change avant et après la récolte de la canne à sucre.

Le sol est très instable et par conséquent potentiellement riche en diverses formes de vie. Les organismes microscopiques, la flore du fond et la faune qui apparaissent et disparaissent suivant l'accroissement des buissons, des plantes cultivées qui seront récoltées plus tard, des herbes qui devraient être récoltées. Des échantillons de sol de différents endroits devraient être ramassés à différentes heures.

Les champs, dans leur sens agricole, les bois, les flancs des collines, ont tous des habitants qui leur sont particuliers et une étude approfondie montre qu'un ruisseau dévalant de la colline ou passant à travers un champ affecte la population de la région. Il faut prendre tout cela en considération au cours des excursions entreprises pour récolter du matériel.

En ce qui concerne les bois, il faut s'intéresser, non seulement aux plantes et aux animaux en liberté, mais aussi à un grand nombre de saprophytes et de parasites qui y vivent. La température, l'humidité du milieu terrestre doivent être notés au moment de la récolte du matériel. Il y a à l'Ile Maurice (et ailleurs, je suppose) un choix d'habitats terrestres qui varie avec l'humidité. Le ramasseur ne doit pas oublier de récol-

ter du matériel provenant d'un endroit sec durant la saison la moins sèche aussi bien que durant la saison la plus sèche de l'année. Ceci s'applique de la même manière aux régions humides.

C'est frappant de voir combien de différence il y a entre la population microscopique des pâturages et celle des terres incultes.

Le ramasseur doit suivre de près tous les événements favorisant la collection de matériel. L'arrivée de la sécheresse permet au collectionneur de récolter un choix de formes de vie provenant des mares desséchées. Les visites aux abattoirs locaux durant les périodes saines et les moments d'épidémie sont également profitables. Il en est de même des hôpitaux et des services vétérinaires. Des tas de débris qui présentent une grande valeur pour le professeur de biologie sont abandonnés par les médecins, les vétérinaires, les fermiers et les pêcheurs : de vieilles radios, des dents arrachées, des plumes par exemple. Ces objets ne coûtent rien, ils peuvent être obtenus sur demande.

Réunir une collection de matériel n'est pas une simple excursion d'école que l'on décide d'entreprendre sous l'impulsion du moment, c'est un exercice scientifique qui doit être préparé en fonction du trajet de l'équipement, des premiers secours et surtout des objectifs.

Un importante factor para el estudio de la biología :
la recogida de muestras sobre el terreno

H.H. Joomaye
(Resumen)

Después de subrayar el interés de la recogida de muestras frescas sobre el terreno (plantas o microorganismos), el autor da cierto número de consejos precisos, establece la lista del material necesario y examina las diversas estaciones explotables : aguas dulces o salobres, suelos, campos y bosques, así como hospitales y servicios veterinarios. Se insiste en la necesidad de preparar y planificar rigurosamente tales ejercicios.

An important element in studying Biology :
collecting specimens in the field

H.H. Joomaye
(Summary)

After having emphasised the usefulness of collecting fresh specimens in the field (plants or micro-organisms), the author gives some valuable pieces of advice. He lists the equipment necessary, and then reviews the various suitable stations : fresh or salt water, soil, fields, woods, and veterinary hospitals and services. He insists on the need to plan and prepare this kind of work with strict accuracy.

LES TECHNIQUES AUDIO-VISUELLES DANS L'ENSEIGNEMENT DES SCIENCES NATURELLES

Mme Debrune, Melle Faure et M. Valérien

Pour les besoins de leur enseignement, les Naturalistes disposent déjà du choix le plus considérable de documents : photographies, diapositives, films 16 mm sonores ou muets, émissions de télévision.

Aussi, lorsque l'Institut Pédagogique National nous a sollicités pour constituer un groupe de travail chargé d'étudier, d'une part les possibilités du film 8 mm, et d'autre part celles de la télévision en circuit fermé, nous sommes-nous posé la question : **De quelle manière les techniques audio-visuelles peuvent-elles, au mieux, servir notre enseignement ?**

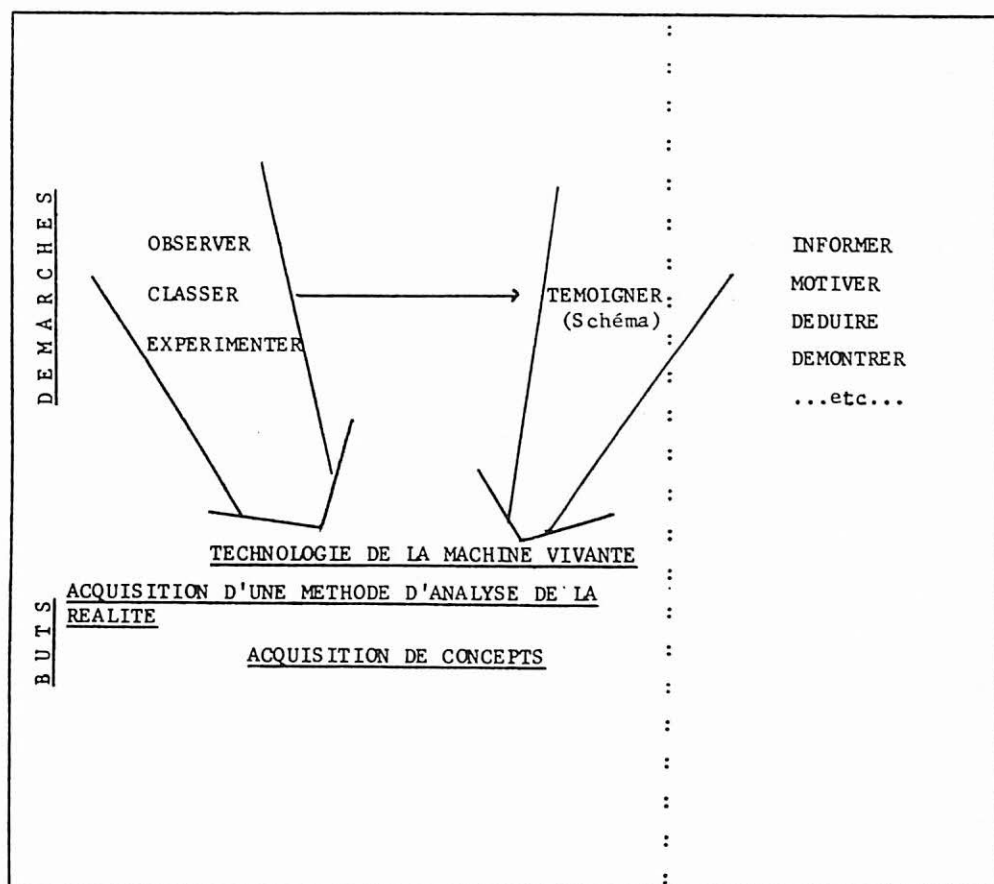
RAPPEL DES BUTS ET PRATIQUES PÉDAGOGIQUES DE NOTRE ENSEIGNEMENT

Les contacts entre collègues sont de plus en plus étroits : réunions dans le cadre du laboratoire, colloques organisés par l'A.P.B.G. et par ses Régionales. Il émane de toutes ces réunions, une recherche collective qui tend à donner à l'enseignement des Sciences naturelles un nouveau visage que soulignent les instructions de l'Inspection générale.

Schématiquement, nous œuvrons dans un triple but :

- Nous menons nos élèves à la découverte de l'organisation de l'être vivant (comment c'est fait) en nous proposant d'en expliquer le fonctionnement (comment ça fonctionne). Nos prétentions dans ce domaine sont grandes : car nous abordons en fait la **technologie** la plus compliquée, celle de la **machine vivante** (alors qu'une technologie beaucoup plus facile n'est abordée qu'en classes de quatrième et de troisième);

- Nous proposons à nos élèves une méthodologie de l'investigation qui doit déboucher sur une vision personnelle du monde qui les entoure ; nous voulons, en quelque sorte, leur faire acquérir une **méthode d'analyse de la réalité** et non leur proposer des modèles qui risqueraient de la masquer ;



- Enfin, nous voulons faire acquérir à nos élèves un certain nombre de notions fondamentales, **de concepts**, lesquels, pour être « empiriques » (3), n'en sont pas moins la base nécessaire au développement de l'esprit scientifique.

Certains buts et pratiques pédagogiques semblent plus spécifiques de notre enseignement.

En particulier, nous demandons à nos élèves d'**observer**, de **classer** et d'**expérimenter**. Pour chacune de ces démarches, l'élève doit rendre compte, doit **témoigner**. Et le témoignage de l'élève, en Sciences naturelles, est caractéristique : il peut certes revêtir la forme écrite, ce qui est commun à d'autres disciplines, mais il comporte le plus souvent une large part d'expression qui possède ses conventions, ses lois propres : le schéma.

(3) Dans la classification des concepts proposés par certains philosophes, les nôtres sont dits « empiriques » parce qu'abstraits de l'expérience.

POSSIBILITÉS ET LIMITES DE L'AUDIO-VISUEL

A) L'audio-visuel au secours du maître ou « S.O.S. audio-visuel ».

Il existe un certain nombre de situations scolaires où l'emploi de l'audio-visuel apparaît comme irremplaçable, car aucune autre technique éprouvée ne peut jouer le même rôle.

— Par exemple, l'étude technologique de l'être vivant ne peut se traiter sans images (activité du cœur « in situ », mécanique intestinale, toute expérience irréalisable dans le cadre de la classe).

— L'observation rentable, individuelle ou collective, de certains phénomènes (déplacements d'animaux, mue d'Arthropode) n'est sûrement possible qu'avec l'emploi des techniques de l'image, seules capables d'**analyser** par le ralenti cinématographique ou d'**assurer** l'observation d'un phénomène non aisément reproductible.

— Et comment faire acquérir les notions relatives aux ultrastructures cellulaires ou aux phénomènes géologiques actuels sans le secours de l'image ?

De même, un chapitre essentiel de notre enseignement, l'Ecologie, justiciable d'une présence constante sur le terrain, ne pourra se passer des apports de l'image.

L'image se présente sous des formes multiples : Photographies sur papier - Diapositives et films fixes - Films 16 mm muets et sonores - Films 8 mm muets et sonores - Images télévisées en circuit ouvert ou en circuit fermé.

Diapositives et films 16 mm sont déjà couramment utilisés dans nos classes. Nous connaissons leurs limites : absence de mouvement pour les diapositives, difficulté d'intégration totale du film 16 mm dans le cours.

Peu d'entre nous connaissent, par contre, les possibilités du film 8 mm et de la télévision intégrée.

LE FILM 8 mm

1. Historique.

Peut-on considérer le film 8 mm comme d'origine française ou voir dans son avènement une influence anglo-saxonne ? Il convient de rappeler que les premiers films d'enseignement furent réalisés en France au début de ce siècle. En Sciences naturelles, ceux des firmes commerciales (Pathé, Gaumont, d'abord seuls, puis en collaboration avec l'Union des Naturalistes) étaient d'une conception assez voisine de celle actuellement prônée : films muets, relativement courts, limités à un seul sujet. Ils étaient loués ou vendus, dans le format 35 mm, puis dans le format 9,5 mm. D'autre part, il convient de rappeler que, pour la première fois, en 1934, Jean PAINLEVÉ présentait à Paris une réduction 8 mm à partir d'un métrage 35 mm (« La Pieuvre »).

Quelle que soit son origine, le film 8 mm proposé aujourd'hui correspond aux vœux des Naturalistes : « Quant au contenu du film, ils désirent un **plan - séquence - enregistrement brut**, c'est-à-dire un film **court** (réduit à un plan ou à une séquence), **muet** (que le professeur pourra commenter lui-même) montrant **mieux** que **tout autre procédé** d'observation et d'enregistrement (la caméra utilisée comme moyen propre d'investigation) un **seul**

phénomène à l'état brut (sur lequel on n'intervient que par le mode d'éclairage, la grosseur du plan ou la fréquence des prises de vues).

Quant au contenant, les Naturalistes désirent un format permettant de constituer à peu de frais une cinémathèque de classe, toujours disponible, et un projecteur souple, léger, maniable, puissant, automatique et perfectionné, bien que très simple. »

Malgré ces exigences clairement exprimées et renouvelées, le film de Sciences naturelles (comme le film, pour les autres disciplines) a été entraîné, de 1936 à 1960, dans une autre direction. C'est que le rapide développement des techniques cinématographiques avait forgé un nouvel outil, le film sonore, en même temps que des structures administratives, comme l'établissement de cinémathèques, permettaient le prêt et la rotation de films sonores en version 16 mm. La plupart de ces films ont une durée moyenne de 10 à 20 minutes : presque tous traitent d'un sujet relativement large. Une monographie d'animal, par exemple, traitera en 15 minutes la présentation, le déplacement, la nutrition et la reproduction de l'animal étudié. C'est alors un film d'appoint qu'il est souvent difficile d'intégrer dans la progression pédagogique prévue par l'utilisateur : ou bien le professeur se tait et laisse parler le film, ou bien il demande au film de redire, sous une autre forme, ce qu'il a déjà dit lui-même. Cette conception du film d'enseignement fut même poussée à l'extrême, avec l'apparition, sur le marché américain, vers 1960, de véritables cours filmés (4).

L'apparition du film 8 mm n'entraîne pas, loin s'en faut, la condamnation du film d'enseignement 16 mm sonore. Il existe de très bons films, très largement utilisés par les professeurs (5). Certains sujets ne peuvent être traités que de cette façon, et l'enseignement doit chercher à tirer parti de toutes les techniques de communication actuelles, donc du film sonore et de la télévision. Mais à côté de cette utilisation « classique » du film « traditionnel », il y a certainement place pour des documents plus analytiques, d'utilisation suffisamment souple pour que le Naturaliste puisse les intégrer sans aucune difficulté dans sa propre progression pédagogique. Cette souplesse est encore renforcée par l'apparition sur le marché de projecteurs entièrement automatiques (6).

Les études préliminaires ont été effectuées en France conjointement par l'Institut Pédagogique National et le Centre Audio-Visuel de l'Ecole Normale Supérieure de Saint-Cloud. Quelques prototypes de films furent réalisés en même temps que des structures administratives étaient étudiées. En effet, la mise en place sur le marché d'un nombre important de films tirés au départ, selon les prévisions de vente, à 1 000 ou 3 000 exemplaires.

(4) Cf. Ces films du programme de biologie de l'A.I.B.S. (American Institut For Biological Sciences) distribués par Mac Graw Hill, New York. On peut consulter certains de ces films à la Cinémathèque Scientifique de l'O.C.D.E.

(5) On pourra consulter avec profit les statistiques de prêts de la Cinémathèque de l'Enseignement public : certains films sont prêtés plus de 700 fois par an, ce qui correspond à 1 000 à 1 500 projections.

(6) Actuellement, un seul projecteur est commercialisé. Le film est présenté dans une cassette plastique dans laquelle il est en boucle. Le maniement d'un tel appareil est extrêmement facile. Ce projecteur n'a pas encore reçu l'agrément du Ministère de l'Education nationale, alors qu'il est en service dans de nombreux autres pays où il donne satisfaction. La mise en circulation d'appareils français sera lente, et l'adoption d'un standard particulier ne favorisera pas l'adoption des films français par les pays étrangers.

posait un certain nombre de problèmes (études de marché, immobilisation de capitaux, installation d'un réseau de vente, etc.) qui ont paru, à tort ou à raison, dépasser les possibilités techniques et financières du Ministère de l'Education nationale. C'est pourquoi celui-ci a négocié une convention avec l'industrie privée (7), susceptible d'apporter les structures et les capitaux nécessaires.

2. Etat actuel de la production.

Un certain nombre de films ont été produits et sont inscrits au catalogue des films de 8 mm distribués par l'Institut Pédagogique National. Ils ont été montrés aux collègues dans des journées d'information organisées par l'Institut Pédagogique National et les Centres Régionaux de Documentation Pédagogique.

Cette première tranche de production ne visait en aucune manière à couvrir les besoins de telle ou telle partie du programme. Nous avons cherché au contraire à réaliser un certain nombre de types de films de façon à **présenter un inventaire de possibilités.**

C'est ainsi que nous avons cherché à exploiter :

- **l'enregistrement radiocinématographique** avec des films sur la digestion, la respiration, la circulation... ;

- **l'observation en aquarium** (possibilités de gros plans, recherche de la continuité d'une action) avec, d'une part, une courte série de documents centrés sur un même sujet (le Crabe) ou, au contraire, avec des documents plus variés (Sépiole, Arénicole, Coque, etc.) ;

- **l'enregistrement d'une expérience**, comme celle qui permet l'observation des valves du cœur (expérience dite de la lunette de Gad) ;

- **l'enregistrement d'une manipulation**, comme par exemple une dissection (petit Mammifère, encéphale) ;

- **l'enregistrement de la dissection de pièces anatomiques humaines** (exemple : le cœur humain) ;

- **la possibilité du schéma animé**, avec un court film sur l'hématose ;

- **la possibilité de l'arrêt sur l'image et de la surimpression** avec les films de radiocinéma ;
etc., etc.

Une seconde tranche de production est en cours. Elle vise d'une façon beaucoup plus précise, d'une part à couvrir un programme (celui des classes de sixième et de cinquième) en mettant un accent plus particulier sur les modes de locomotion et de nutrition, lesquels font intervenir les techniques d'accélération, de ralenti et de macro-cinéma ; d'autre part, à satisfaire les demandes le plus souvent formulées par les collègues enseignant en classes terminales (enregistrements d'expériences de physiologie difficilement réalisables en classe).

3. Vue prospective.

Un effort très important de production et d'équipement en vue de la production a été réalisé par l'Institut Pédagogique National. Pour que l'opération 8 mm puisse prendre sa véritable ampleur, il convient qu'elle

(7) COFEC (Consortium du Film Educatif, réunissant les Sociétés Pathé, Gaumont et Tadié Cinéma).

devienne, de plus en plus, l'œuvre de tous les collègues concernés et intéressés.

Cette œuvre commune doit se traduire par l'apport de chacun d'entre nous — ou mieux par un travail particulier de chacun des groupes constitués soit à l'intérieur d'un établissement, soit dans le cadre d'une Régionale.

Ce travail peut prendre divers aspects :

— ce peut être, dans un premier temps, **une analyse critique et constructive** de ce qui existe déjà, de façon qu'une erreur ne soit pas renouvelée ou qu'un type de film, qui ne donne pas satisfaction, soit abandonné. La Commission ministérielle d'Etude et d'Agrément, qui cautionne les documents qui lui sont présentés, est vivement intéressée par l'avis des utilisateurs ;

— ce peut être **des idées de films à réaliser**. Tel professeur demande tel ou tel document. Il faut toutefois remarquer que s'il est toujours tenu compte des demandes (et en priorité des plus répétées) cela implique un certain délai. Ceci pour des impératifs financiers et techniques beaucoup plus que pédagogiques. (Pensons que l'équipe de production travaille selon un planning qu'il n'est pas toujours possible de modifier ; — que notre discipline n'est pas la seule : un volume de production est déterminé pour chaque discipline ; — qu'un film, nécessitant une technique particulière, immobilise un matériel coûteux pendant longtemps et que ce film peut n'être rentable que s'il existe un certain nombre de films à faire comportant la même technique et justifiant ainsi l'acquisition d'un matériel cher...);

— ce peut être encore, mieux que des idées de films, de **véritables découpages** avec la **succession d'images** et le **texte accompagnateur prévisionnel** comportant les intentions du film, sa justification et un projet de commentaire pour l'utilisateur ;

— ce peut être enfin le **film tout fait**, réalisé avec les moyens du bord. Certes, ce film tout fait ne sera pas bien souvent utilisable tel quel, et ceci pour deux raisons essentielles : d'une part, on ne s'improvise pas gens d'images et tout film produit par l'Institut Pédagogique National doit respecter **une certaine qualité** qui permette la vente ou l'échange du document à l'étranger ; d'autre part, le film doit être reproduit en un certain nombre d'exemplaires, ce qui met en jeu non seulement la qualité des images, mais encore la qualité du support de la pellicule utilisée. Le transfert des images d'une pellicule sur une autre coûte parfois plus cher (et donne le plus souvent des résultats décevants) que de refaire le film. C'est pourquoi le film tout fait sera le plus souvent considéré comme film d'essai à partir duquel sera exécutée, par une équipe technique, une version définitive.

Il va de soi que dans les deux derniers cas, les auteurs du projet détaillé ou du film d'essai seront les auteurs — c'est-à-dire les conseillers pédagogiques — du film élaboré. **Il n'est pas utopique de penser que dans un proche avenir, l'Institut Pédagogique National sera en mesure soit de faire venir les conseillers pédagogiques auprès de ses équipes techniques, soit d'envoyer ses équipes de prises de vues auprès des conseillers pédagogiques.** Et ceci sera d'autant plus possible que, dans le cadre d'une Régionale, par exemple, les projets seront regroupés de façon à réduire les frais inhérents à l'implantation d'une équipe technique loin de ses locaux habituels.

Dans cette vue prospective, ne serait-il pas souhaitable que, chaque année, le bulletin publie le programme de production de l'Institut Pédagogique National ?

LE CIRCUIT DE TÉLÉVISION INTÉGRÉ

C'est l'outil pédagogique le plus récent, pour lequel l'Institut Pédagogique National a créé un nouveau service, **celui de la télévision intégrée**. Depuis quelques années, des expériences sont en cours, plus particulièrement au Lycée de Sèvres, à l'Ecole Alsacienne de Paris, au Lycée de Liévin, au Lycée de Saint-Quentin. Déjà, deux séminaires ont réuni les premiers utilisateurs naturalistes : en mai dernier au Lycée de Liévin, en septembre au Lycée de Sèvres.

Au Lycée de Liévin furent confrontées les premières expériences, au Lycée de Sèvres ont été tirées les premières conclusions que nous empruntons au rapporteur du séminaire Sciences naturelles (8).

Parmi les types d'utilisation du circuit intégré qui ont été examinés, nous retiendrons seulement l'emploi du circuit fermé pour la conduite des travaux pratiques.

Cette première utilisation suppose un appareillage relativement modeste installé dans **la salle même où se déroulent les travaux pratiques**. Le plus souvent, une seule caméra, en position verticale (ou avec renvoi à 45° par miroir) est placée au-dessus d'une table d'analyse, l'ensemble constituant ce que l'on désigne par le terme « lecteur de documents » ou télélecteur. La table d'analyse permet :

- de lire toutes images opaques (éclairées par-dessus) ou transparentes (éclairées par-dessous) ;
- d'examiner et de grossir des objets, des dissections, etc. ;
- souvent la caméra peut basculer sur un microscope et cela permet l'exploration des lames (dans certaines installations, une caméra spéciale est affectée au microscope ; dans d'autres, l'utilisation d'objectifs spéciaux et de bonnettes permet de grossir directement la lame sans passer par l'intermédiaire du microscope).

Les images données par la caméra sont retransmises **directement** sur le ou les récepteurs de la salle de classe. **Les élèves participent donc à la recherche, à la mise au point, à la composition des images faites par le professeur, le technicien ou l'un des élèves.**

Le système est donc en fait **une loupe collective**.

Cette utilisation, essayée plus systématiquement par le Lycée de Liévin, est **très** satisfaisante et ne pose **pas** de problèmes.

Le professeur pourra transporter rapidement sous le télélecteur ou le télémicroscope une préparation présentant une particularité biologique ou morphologique intéressante (Paramécie en division, Crabe parasité par une Sacculine, etc.) qui pourra être vue par tous.

Les élèves pourront participer à la recherche de la région intéressante d'une coupe microscopique, l'approche se faisant devant eux sur l'écran.

De même, ils suivent très facilement les étapes d'un dissection.

(8) M^{me} LE STRAT, Professeur au Lycée de Sèvres.

Toutes ces possibilités facilitent les observations et les exercices individuels que les élèves doivent effectuer. C'est pourquoi les participants des séminaires, unanimes, se sont montrés favorables à la télévision employée dans cette optique et demandent qu'un outil pédagogique aussi remarquable puisse être mis à la disposition des Naturalistes.

B) Les dénigrants de l'image ou « défense d'afficher ».

Il n'en reste pas moins que l'audio-visuel a ses opposants... (réductibles).

Quels sont les reproches le plus souvent formulés ?

- Il y a trop de documents.
- Il est difficile de les connaître tous.
- Il est difficile de les choisir et de se restreindre.
- L'image déforme la réalité (documents artificiels).
- La composition de l'image supprime une part d'investigation personnelle de l'élève.
- L'emploi de l'image constitue une perte de temps.
- L'élève est passif, il ne participe pas.
- Le message transmis par l'image semble évident, et cependant les élèves ne l'assimilent pas.
- L'usage d'appareils d'un maniement parfois complexe introduit une difficulté supplémentaire pour le professeur.
- L'image télévisée est en noir et blanc.
- L'utilisation de la télévision en circuit ouvert (émissions de la R.T.S.) suppose un aménagement des horaires.

Tous ces arguments sont à prendre en considération et, avant d'y répondre, nous aimerions connaître l'avis motivé de nos collègues.

PERSPECTIVES D'AVENIR

Dans tout ce qui précède, on a considéré le document audio-visuel comme asservi à l'enseignement traditionnel (départ ou complément indispensable de celui-ci).

C'EST ENCORE L'OPTIQUE DE LA PLUPART D'ENTRE NOUS.

Mais déjà un ensemble d'expériences prouve qu'on peut envisager une optique nouvelle et sensiblement différente.

Aux lycées de Sèvres, Saint-Quentin, Liévin et à l'Ecole Alsacienne, **des équipes de professeurs** emploient la télévision pour des émissions de documentation, d'information et de synthèse.

Cela suppose tout d'abord que l'établissement dispose d'un appareillage complexe comportant :

— une **salle émettrice**, qui peut être un **studio** (Sèvres, Liévin, Saint-Quentin) ou une salle de classe pouvant recevoir ou non des élèves (Ecole Alsacienne). Cette salle émettrice est couplée avec une **régie** où sont rassemblées les différentes images provenant :

- de caméras mobiles,
- du lecteur de documents,
- du télémicroscope,
- du lecteur de diapositives,
- du télécinéma

(chaque installation pouvant être plus ou moins complexe).

C'est en définitive de la régie que l'image sélectionnée est envoyée avec un son correspondant, sur les récepteurs qui équipent un certain nombre de **salles réceptrices**.

La maintenance de cet appareillage, la réalisation des émissions demandent une équipe technique plus ou moins importante (deux personnes).

Dans un établissement ainsi équipé, le professeur se trouve placé devant le choix suivant : ou bien il **travaille seul** (il peut, par exemple, demander à la technique l'envoi de tel ou tel document à tel ou tel moment particulier de son cours, ou bien préparer à l'avance une émission pour ses propres élèves) et dans ce cas particulier il n'y a guère de problèmes, sinon qu'il est utopique de mobiliser un tel appareillage pour une seule classe et de demander au professeur un travail très lourd ; — ou bien il **travaille en équipe** (Sèvres, Ecole Alsacienne), et **ce travail d'équipe apparaît bien vite indispensable**.

Dans les deux expériences (Sèvres, Ecole Alsacienne), les séquences télévisées étaient reçues par plusieurs classes de même niveau. Au Lycée de Sèvres, deux classes de troisième étaient rassemblées dans une salle commune sous la surveillance d'un « professeur récepteur », l'autre membre de l'équipe étant « professeur émetteur ». Les deux enseignants alternaient dans ces rôles. En effet, la présence d'un professeur a semblé indispensable à la réception. Cependant, le professeur récepteur a eu de grandes difficultés à se transformer en surveillant des élèves et observateur de l'émission, alors qu'il ne connaissait que la moitié des participants.

A l'Ecole Alsacienne, le problème est un peu différent ; les trois classes de troisième recevant la même émission restent chacune dans leur salle, avec leur maître, une salle de classe étant « émettrice », les deux autres « réceptrices ».

Le travail d'équipe entrepris est jugé bénéfique ; les professeurs préparent ensemble une progression, discutent ensemble des émissions et élaborent celles-ci à tour de rôle. Le résultat de cette collaboration entre spécialistes est évidemment original et spécifique du groupe qui l'a réalisé en tenant compte des problèmes particuliers posés par les classes intéressées. **Ce travail ne saurait donc être utilisé par des professeurs n'ayant pas participé à son élaboration et ne saurait être, en particulier, imposé comme émission-type à d'autres établissements.**

D'autres problèmes se posent : en dehors du problème de l'encadrement (rôle du professeur récepteur) existe celui du rythme d'acquisition des connaissances qui peut varier d'une classe à l'autre : il convient donc de prévoir des séances de réajustement (par exemple, une toutes les émissions ou bien une toutes les deux émissions). Le problème du dialogue professeurs-élèves a été longuement débattu : en fait, il semble que la télévision favorise la discussion maître-élève plutôt qu'elle ne la limite : en effet, on discute facilement de l'émission et il y a là une possibilité de contacts spontanés et directs qui peuvent être fructueux.

L'expérience la plus importante est sans conteste celle tentée au C.E.S. de Marly-le-Roi qui a été spécialement conçue pour jouer à plein la carte de l'audio-visuel.

Encore non entièrement construit, il a cependant ouvert ses portes cette année aux élèves de sixième et accueillera l'an prochain les élèves de sixième et de cinquième. Les retards apportés à la construction font qu'il

s'agit cette année d'une préexpérience, préexpérience qui permettra d'ailleurs d'ajuster les hypothèses de départ.

Ces hypothèses, quelles sont-elles ? Elles reposent en fait sur l'analyse de contenus confiée au séminaire que nous animons.

Notre travail a tout d'abord consisté à découper le programme de l'année en un certain nombre d'unités ; ceci pour respecter à la fois le programme, les horaires et les instructions officiels.

Pour chacune des unités retenues, nous avons ensuite essayé de définir des intentions pédagogiques précises : telle leçon sur le Chat en sixième ou sur le Crabe en cinquième, pourquoi les faisons-nous ? Cela conditionne évidemment le contenu de la leçon. S'il entre dans nos intentions de faire comparer, lors de la première étude de Mammifère, l'organisation du corps humain avec celle du Chat ou du Lapin, il conviendra de prévoir une dissection qui pourra prendre diverses formes : dissection par l'élève, dissection par le professeur pour l'ensemble des élèves, image fixe ou animée.

Parallèlement à cette définition d'intentions, on pourrait dire de justification, le contenu de chaque unité est analysé de façon précise afin de regrouper, d'une part, le vocabulaire spécifique à utiliser, et d'autre part les notions que l'élève doit avoir acquises à la fin de la leçon.

Ainsi, un véritable démontage de chaque unité est effectué et l'on se trouve finalement en face des différentes pièces d'un puzzle. **Reste à chaque professeur de reconstruire le puzzle avec les armes qu'il juge les plus appropriées.**

Prenons, par exemple, la troisième unité prévue et étudiée pour la classe de sixième qui porte sur les dents. (Précisons que cette unité est précédée tout d'abord par une leçon qui pourrait avoir pour titre : « Qu'est-ce qu'observer » et d'une seconde unité portant sur l'organisation du corps humain.)

Pour cette unité, nous avons défini :

- des intentions pédagogiques qui visent essentiellement à donner aux élèves le **concept de dent**, ce concept étant acquis tout particulièrement par la manipulation de dents dont l'élève devra faire un schéma précis. Ce sera son premier schéma (en effet, dans l'unité précédente, l'élève n'a pas eu à dessiner, mais à mettre des légendes sur des dessins préparés à l'avance) ;

- un vocabulaire spécifique ;

- un ensemble de notions que l'élève devra avoir acquies ;

- un matériel de base ;

- un travail individuel de l'élève (sous forme de travaux pratiques dirigés, mais aussi des exercices libres).

Il appartient aux professeurs en situation, qu'ils utilisent ou non les pièces de ce puzzle, de construire effectivement la leçon sur les dents, en ventilant les différentes pratiques pédagogiques.

On peut, par exemple, proposer :

1. Dans un premier temps, une émission de télévision destinée à l'ensemble des élèves. Cette émission doit poser un problème et introduire le travail pratique individuel. On présentera, par exemple, longuement, de face et de profil, un sujet qui mange une pomme. Le fait de manger sera mis en relation avec le fait que nous avons des dents.

2. Ensuite viendra le travail pratique dirigé. Chaque élève disposera au moins d'une dent qu'il devra observer. Il aura ensuite à rendre compte par un schéma (dont l'élaboration pourra être suivie au télélecteur). En une heure, l'élève doit faire un dessin correct. (Du matériel sera tenu en réserve pour le cas où un élève aurait terminé avant la fin de l'heure.)

3. Dans un troisième temps, collectif celui-ci, une émission de télévision aura pour but de relier le concept anatomique de la dent, qui aura été abordé et pourra alors être précisé, au concept fonctionnel de dent. On pourra alors passer aux différents types de dents : l'ajustement entre la forme, la situation et la fonction. Malgré les différentes formes et les fonctions particulières, il n'en reste pas moins un concept général de dent. Si on le désire, on pourra ensuite donner une information sur la vie de la dent (dent de lait, bourgeon dentaire, dent de remplacement, dent de complément).

4. Enfin, dans un dernier temps, l'élève aura un travail personnel libre à effectuer (ce travail pouvant être dirigé par une fiche ronéotypée à l'avance). L'élève pourra, par exemple : établir sa propre formule dentaire sur une feuille de Sécurité sociale et la comparer à la formule dentaire de l'adulte.

Ceci n'est, bien entendu, qu'un exemple de progression excluant l'emploi de la télévision. Mais tout est possible ; travaux de groupes, emploi de séquences en couleur (films 8 mm), etc. Le travail des professeurs en équipe permet l'essai de **nouvelles structures** (un grand nombre d'élèves peut suivre l'émission, de petits groupes manipulent ou travaillent en commun ; l'élève seul fait un travail individuel), **une nouvelle répartition des tâches** (les émissions préparées en commun sont, soit réalisées à l'avance si cela est nécessaire, soit faites en direct à tour de rôle selon les compétences et les spécialistes...), ainsi que **la création de nouveaux documents** (émissions préparées à l'avance ; série de documents individuels pour un travail libre de la part des élèves, travail qui prolonge l'observation faite en travaux pratiques, par exemple, etc.).

Telle qu'elle s'annonce, l'expérience est **passionnante** et **objective**. Il convient d'en suivre le déroulement et d'en tirer, au fur et à mesure, les enseignements.

Les Thyrses.

Debrune, Faure y Valérien

(Resumen)

La enseñanza audiovisual en biología tiene por objeto conducir al alumno al descubrimiento de la organización del ser vivo, hacerle adquirir un método de análisis de la realidad e inculcarle conceptos que, aun siendo empíricos, forman la base del espíritu científico. Por lo tanto, el alumno debe observar, clasificar y experimentar.

Los medios audiovisuales son un auxiliar indispensable del profesor para presentar los fenómenos de la vida. La película de 8 mm permite registrar procesos como la digestión. La respiración y la circulación, así como un experimento o una disección, la observación de un acuario, etc. En el artículo se indican otras posibilidades y perspectivas futuras.

El circuito de televisión integrado funciona como una lupa colectiva que permite, por ejemplo, seguir fácilmente una disección.

La enseñanza audiovisual considerada como un medio auxiliar presenta, sin embargo, ciertos inconvenientes que los autores exponen objetivamente. De todos modos cabe concebir el desarrollo de la enseñanza audiovisual sobre nuevas bases mediante la colaboración de grupos de profesores que procuren construir a partir de ella nuevas estructuras pedagógicas. A ese respecto se formulan interesantes sugerencias.

Audio-visual techniques in teaching natural science

Mrs Debrune, Miss Faure and Mr Valérien

(Summary)

The aim of audio-visual teaching in Biology is to encourage pupils to discover the pattern on which a living creature is organised, ensure that pupils acquire a method for analysing observed reality, and instil into them the kind of concepts which, although they are empirical, are basic to the scientific outlook. Pupils should accordingly observe, classify, and make experiments.

Audio-visual media are an indispensable class-room aid for demonstrating living phenomena. 8 mm film can be used to record processes such as digestion, respiration, and circulation; or for example to record experiments, dissection, or the observation of an aquarium. The article indicates other possibilities and future prospects.

Closed circuit television works like a collective magnifying-glass, making it possible for example to follow a dissection without any difficulty.

Considered as a teaching aid audio-visual methods do have some disadvantages, which the authors describe objectively. It is nevertheless possible to envisage the development of audio-visual teaching on a new basis, on which teams of teachers will try to build new teaching structures. Valuable suggestions are made to this effect.

THE FILM IN BIOLOGICAL INSTRUCTION AND IN SCIENTIFIC INFORMATION

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I. THE HISTORY OF FILM TECHNIQUE IN THE FIELD OF BIOLOGY

Almost a century has passed since the day in 1872 when Director Muybridge of the US Government's Photographic Service studied the movements of a horse named "Occident". This period has proven that the film, discovered by scientists to help in their study of movement, is an inseparable part of biological research. It is a method of observation and simultaneously a means of transmitting and, if need be, evaluating scientific information. Today, therefore, the use of the film in biology is part of the means and methods of scientific work, of new methods in scientific analysis. From the development of cinematographic technique, used in biological research, it is obvious that the scientific importance of cinematography in biology has grown in proportion to the interest in the time course of natural processes.

The first pioneers of scientific cinematography in the Marey Institute in Paris constructed their own apparatus for scientific cinematography, but today this is a new branch of engineering technology. Professor Commandon was still the embodiment of scientist and engineer in one person, when he constructed the apparatus for microscopic pictures. Today scientists have at their disposal a far more complex apparatus even for long-distance viewing of pictures. In biology, simple photographic apparatus has been replaced by more complex apparatus, filming technique has been perfected and adapted to different conditions, i.e. to the environment, size, observation conditions of the working place and to the photographed object.

Registrative film methods developed from observation times, based on the powers of the human eye. These methods augmented the possibilities of observation, perfected the means and permitted more accurate observations. Accurate observation is, generally, a repetition of observations, and this is possible with cinematographic projection. Thus, the botanist Pfeffer of Leipzig obtained the first slow-motion pictures of plants in 1899. In 1903-1904 Lucien Bull constructed the "ultrarapid cinematograph" which took 5000 pictures per second, to be able to photograph the flight of insects. In about the year 1919, Professor Carvallo succeeded in taking the first X-ray cinematographic pictures of the functioning of the stomach. One year later Dr. U.K.T. Schulz filmed a high speed ballistic action.

In some branches of biology, photography and later cinematography have become indispensable ; these branches developed following the introduction of cinematography and photographic material. To what extent a filmed picture is an objective record of reality, depends on the type of shots. Cinematography, for instance, observes the form, structure and movement of microscopic objects and reproduces the changes. In this way, Dr. Commandon discovered the principle of the movement of tentacles, Professor Belehradsek the movement mechanism of the *Vorticella* protozoan. Cinematography, as the Botanist Academician Bohumil Nemec once said, after seeing the film "The Cultivation of Tissues", is the biologist's substitute for often long, continuous, tedious subjective observation, which it has refined and made into a scientific method. In biology the means of expression through pictures and action of observed processes are often a component part of scientific information. Some biological knowledge is almost unconveyable without pictorial expression. Academician A.J. Oparin claims that "many processes could hardly be studied without the film".

Today photographic technique can be applied to nearly all research methods in biology, optically, photochemically or electronically. As an interesting example let us mention how in the year 1897 Oskar Messter together with Professors Spiesse and Lubasch solved the problem of photographing a cat pouncing on all fours, using a speed camera with a 60 mm unperforated film. At 66 pictures per second they learned that the cat turns from a spinal position to a stomach position in one tenth of a second. Simultaneously, they photographed a Hippsch milli-second watch and to the right of the pictures two falling balls, one of steel, the other of wood and their shadows on a decimeter scale. Film technology has greatly developed since those days. Today we have developed a technique using ultramicroscopes, radiocinematographic technique, the film technique using micromanipulators and even more complex apparatuses. Using these leads to a great number of biological documents which can retain the knowledge for a longer period of time, permitting analysis at a later date and thus leading to new discoveries which may have been unexplainable or gone unnoticed during the actual filming process.

The amount of new biological knowledge, or visualization of biological objects attained by different methods of cinematographic filming and other means of optophonic registration are, however, still not fully utilized in scientific communication. We restrict ourselves to older methods of communication and have not attempted to extend the conclusive evidence of scientific proof to filmed material that is not dependent on the subjectiveness of the research worker.

The results of an examination on the use of film technique in the making of scientific films at American universities in 1960-61 have shown that the following techniques were used : high-speed cinematography 165 films, time lapse cinematography 136, normal frequency film 85, microphotography 100, macrophotography 15, infrared 8, ultraviolet light 2, oscilloscopy 47, polarized light 27, schlierencinematography 15, interference 11, radioscopy 3, fluorography 2, radiography 12, spectrophotometry 2, stroboscopy 2 takes.

A total of 16 different methods of shooting were used of which the majority were applied to biology. Thus, the valuable use of films in biology requires the pooling of apparatus technique, and of experts with knowledge of the technique at the disposal of scientific workers.

The scope of the applied technique shows that workers in the field of biology should be more thoroughly and consistently prepared for the use of this technique than hitherto, in the course of their studies.

II. METHODS OF CONVEYING BIOLOGICAL KNOWLEDGE VIA THE FILM

The subjects of biological films are determined by the problems arising from research or instruction. We may divide them according to specific structures, regularities of biological processes, forms of motion and function. The film captures either the natural objects, micro and macro-objects, stationary structures or signs of life, artificial cultivation, etc. These objects and the possibilities of their study determine the use of the filming technique.

The space, in which the film is shot, determines the conditions of the pictures, the progression of film description of the object or action, is restricted by dimensions of time and space. Mathematical methods are also being applied in biological films, to evaluate the relation of time and space or summarize the results of observation in a graph.

The filmed protocols of biological processes are sufficient for the expert, he does not need a commentary. It is more important to him to know the technical data of the pictures. This direct transmission and transformation of biological knowledge through cinematographic pictures has a proven scientific value and has been acclaimed as a type of scientific work, published by the film. As a result in biology the film can play an increasing part in international scientific cooperation.

In the teaching of biology, the film is a lively illustrative form making use of large details and repeated scenes which make for better understanding. Pictorial documentation in biological films partially prevents incorrect interpretation and restricts the possibility of misunderstanding which could occur through mere verbal description. It helps the understanding of the given phenomena by means of a selected and unchanging example, not restricted to time or place. In the teaching of biological sciences, the film is a suitable method for creating the habit of gathering new knowledge independently, for mastering algorithmic scientific generalisation and not by mere acceptance of knowledge at its lowest level. The film can also be a speedy informer on the state of any specific branch for workers in related scientific fields of specialization and thus cooperate in abolishing the after effects of a disintegrated science, arising from specialization.

Let us now take a look at what happens to biological information that is recorded and transmitted by the film. The film offers a certain amount of knowledge, either simply registered by film technique or pre-

determined and adapted to the level of the audience by the type of film shots. If this is accompanied by a commentary, this pictorial information has an illustrative meaning. Motion makes communication by pictures possible. Changes in size or increase in area call for numerical communication. Changes in time and space are then conveyed by a graphic evaluation of the pictures. Biological development, passing through time, can be summarized by film or spread out into a series of static pictures or into a dynamic picture of a film loop in the definite time interval. These kinds of pictures make observation and comparison of changes much easier. Information imparted through a biological film is almost equal to direct scientific observation and therefore transmits information on a scientific level. The fact that it is observed immediately, without another intermediary, excludes possible error through explanation. In the material content of biological films there is a certain reserve of information needed for the high level of instruction, generally demanded for practice at universities and for the education of scientific workers. Since the filmed sequences are comprehensible to the expert, these films do away with the language barriers and have a wide field of use internationally.

In preparing the filmed biological sequences for purposes of communication it is necessary to acquaint the audience with cinematographic technique used in the pictures and pay particular attention to the quality and genuineness of the pictures. We select a specific length of sequence so that the audience has sufficient time to observe the process or the process changes. The filmed information is transformed particularly in shots with time magnification or the time-lapse method, or with light or space reduction by which we can widen the methods of biological research.

In films where we present the methods of accurate and careful observation of a certain process, we help to improve the scientific training of the spectator, heighten the sensitivity of some analyzers, and by repeating the sequence we train the powers of observation. Direct legibility or intelligibility of the biological pictures is then in accord with the standard methods of observing biological processes in accord with the psychophysiological disposition and power of combination of the observer. The least deformation of biological information is found in the short sequences not complicated by other takes. The fact that a biological scientific film is both a means of evaluation and of mass instruction, has, as E. Huxley has emphasized, brought scientific cinematography closer to scientists as an audience.

At times, biological films use an intermediary between film picture and information. For example, the British films on embryonic development used animated diagrams or schematic color drawings. The animated drawing makes those parts of the process that cannot be observed by the naked eye more understandable. For the most part this has to do with cell and genetic processes, nuclear changes, etc. Biological films, made in leading scientific institutes, serve as information on the method of work and the discoveries of leading scientists. Although scientific films grow old with the development of science and in the passage of time, they lose none of their value since they become a document of the development of biological sciences.

In the light of new scientific knowledge, cinematography is still awaiting its development as an immensely valuable method. This calls for further adaptation of the apparatus and film reel. In conveying or evaluating certain biological phenomena simple observing the film is insufficient even if the pictures are enlarged. Such takes should be evaluated separately. The limits and possibilities of this evaluation are determined by the type of film technique used in making the filmed record and the kind of film material used. Evaluation by a pictorial and time analysis of the shots is made with precise measurement and by ascertaining the mutual relations of the individual pictures. Such a filmed assessment is also important since knowledge gained by the film is reinforced either in written form or graphically and thus the communication of the results of biological research is made easier even without the use of the film.

We make an evaluation in the following manner :

- 1) by projecting the film, and observing the course of action or objects either directly visible or rendered so. The film can be projected at different speeds. The filmed sequences remain unchanged during repetition, or we can begin from a certain stage of development. The reserve course of projection can also be used, or we can stop the film at any picture. Another manner of evaluation is by marking the movements of the individual parts with points or by curves.
- 2) by arranging the fields of the pictures one next to another, which permits us to follow the individual pictorial phases in successive development. We can cover the pictures at certain equal intervals or gradually widen the outline by the chronophotographic method. An indivisible part of the filmed sequences allocated for evaluation are the time markers. As a rule we evaluate the enlarged static pictures on which are shown the criteria and relating points necessary for calculation.
- 3) by localising one point of the picture without regard to the surroundings.
- 4) by photogrammetrical measurements during which we obtain time measures, direction and distances from which we can, if need be, draw up a diagram or table.

Frequency influences the evaluation of the shots. This is known from the speeded-up amoeboidic movements of protozoa and from the rapid separation of the dividing cells, after excessive speed up of the microcinematographic shots. However, the distorted impression from direct projection does not affect the accurate evaluation. Moreover, for example, the estimate of time necessary, in the individual phases of division, is not accurate, particularly if we change the frequency during the individual filmed phases. Fixing the space and time of the takes and the measure of scientific conclusive evidence related to them, is important particularly for filming undiscernible or invisible processes. It is known that for changes in time and conceptions of ultrashort times, we do not have our own observation experiences. That is why we often create an erroneous hypothesis, which cannot be confirmed during the checking of the pictures. In

the practice of evaluating biological filmed sequences, it is, therefore, important to prescribe possible errors. For example, the time markers determine the time with a precision of 0,1% .

In its entirety, precise information imparted by biological films should be compiled with regard to the special shooting methods demanded by different biological films. In order to comprehend the information it is necessary to know and explain the techniques of shooting, determine the speed and the number of pieces of information in accordance with the sub-titles or running commentary. At times the best explanations are those given by an expert for a silent film.

III. THE USE OF THE FILM FOR IMPARTING BIOLOGICAL INFORMATION FOR TEACHING PURPOSES

If the biological film is to become an established form of scientific information and instruction, it will be worthwhile to consider the following problems :

Ascertain the role of the film in biology for disseminating new scientific knowledge and to what extent it helps in extending the use of new discoveries in practice.

To work out a method of using biological films in biology teaching at various school levels and a suitable thematic plan of film production, which would make such instruction easier and better.

To compile oral and pictorial information in a basic group of biological films, on the newest biological discoveries and classic themes for use in a system of scientific instruction and practice, for the international use of this filmed biosophy.

An evaluation of biological films from the point of view of teaching has not yet been carried out with sufficient accuracy. We still have no method of determining, the amount of information contained in biological filmed records in a scientifically precise manner. We still do not know the processes by which we obtain information and what information is obtained from the film and how the spectator conceives it. In order to provide the conditions for the successful utilisation of biological films, it is necessary to ensure a projection technique suitable for a lecture room or laboratory. The degree of specialization would then depend on the detailed content of the film with reference to the preliminary preparation and knowledge of the audience and thus an appropriate amount of new scientific information would be at the disposal of the lecturer.

In this way biological instruction ceases to be descriptive and becomes experimental. This fact also influences the length and extent of the material in the biological films intended for teaching purposes. These new learning aids will make way for further studies. Illustrations in biological films make studies simpler and facilitate obtaining information from related

fields. It can simultaneously be a type of research work because we may observe phenomena not previously noticed in the repeated projections and this can serve for further research.

It is important to have a study curriculum and procedure of supplementing this with films and to respect these principles in the making of the films. In other words, the purpose for which films are to be used should be precisely stated. In biology, for instance, there are various levels of instruction with which to interpret the cell and cell division. However, we still do not have a method of instruction in teaching about cells at a university level. As a result, the Council of Europe is preparing a serial of 12 films on cells this year, which will be prepared in sections at the scientific institutes of seven States that have the best filming techniques in the various fields. A similar project is the group of 48 thirty-minutes films from the field of genetics "Principles of Genetics" from the USA, intended as an introduction for the first year course on genetics. The film was produced in accord with the book of the same name. It was produced in 1961 at the initiative of McGraw Hill, who consulted some of America's leading geneticists and incorporated the help of biological institutes. A summary of the texts of the individual parts of the filmed serial, were published in a guide to the film. Such a film is also of historical value, a document on the state of contemporary genetics.

The attention of all scientists must be aroused if we are to see a greater extension of biological films. According to G.E.H. Foxon of England, 16 out of 21 professors of Zoology, 2 out of 9 teachers of Botany, made use of the film in 1960. In the current university curriculum we restrict ourselves to the more complex chapters of biological subject matter. Difficult subject matter, in addition to the real documents, is often presented through an animated drawing as was shown in the English film on embryology. The interest of scientists in biological films will also increase through the communication of the newest results in scientific research through the films. But it is necessary to have the published scientific results of the films evaluated in the same way as any other scientific publication. This could eliminate the hitherto random use of films in the instruction of biology.

One of the advantages of the biological film is that the spectator can acquire knowledge from the situation to the discoveries, and such a method of learning is much more effective than the mere imparting of information. Biological films are, therefore, a suitable media for learning. From them we could create certain self-instructional systems, programmed in their composition. These serials could be available when a suitable teacher was lacking, or as a means of evoking interest in a particular problem, that is, a kind of motivation.

In biology today the areas that until recently were on the outskirts of scientific interest are now becoming the centre of research. This research is often effected by expressing pictorially and sequentially the processes being observed. In such cases, too, the biological film has more of a purpose, is simultaneously a method of scientific research, a means of observation, registration and evaluation of processes and a method of

scientific communication or instruction. For this reason it can also be used at various levels of learning : in the filmed records whose original shots are several meters long, in longer films (up to 15 minutes) in accordance with the logical development of the problem, which in picture form evoke curiosity or discussion, provided they directly present the examples and ideas for individual, let us say, laboratory activity.

Different composition of the film is used for different purposes so that film instruction is commensurate and communicable to a certain level of audience. Insight 67, the international review of scientific films in Canada, can serve as an example. It is a three phase review intended for three different types of audiences. For scientists they present a program of research films that describe the latest development of different scientific branches. For students, they provide a series of films which supplement special studies and direct them in a scientific direction, and for the public a new review of modern technology that greatly influences our contemporary lives. The review also includes seven categories of biological films from the following countries - two from Canada and the USA, one from Poland, Bulgaria, the Soviet Union, France and Japan.

There is a greater use for biological films in TV educational and school programs and in the future in programs from the telecommunication satellites. From the point of view of expanding scientific knowledge, it will also serve for providing scientific information, scientific and laboratory instruction, the registration and imparting of new scientific discoveries and for the international exchange of scientific information. Films can be an effective part of postgraduate education in biology, approximately to the following extent :

System of Exposition System of disseminating knowledge	Activity and processes	Level of instruction	Group of structure	Aim of the film
Film lecture TV courses	Principles of Sciences	Supplementing basic knowledge	Group Individual	System of education
Loops Trick films Film instruction Film concept	Practical application	Supplementing qualifications	Group Exercises of individuals	Improving qualifications
Film shots Scientif. information by the film Film concept	New discoveries Disseminating news	Development of scientific fields	Group Congresses	Scientific news information
Scientific document	Scient. information in the field and in related	Use of knowledge in related fields	Group Post-graduate	Complex research and Communication

In 1963 biology classes via TV were introduced at the Santa Barbara University. This was group instruction for 20-50 students ; the TV lectures lasted 40 minutes and were prepared by 12 teachers in different branches. The professor introduced the lesson and direct the entire course. Comparatively few lectures are televized directly, most of them are taped.

In contrast to telecasting, the film is at an advantage in conveying scientific information, in working out the film and in its composition, but TV has the advantage of being able to contact larger audiences. Both forms, today, are becoming a part of postgraduate studies and therefore in the field of biology, with the possible increased production of biological films, can be used with success. They can help do away with schematic handling of subject matter, and contribute to the explanation of difficult passages. However, it will be necessary to make the existing biological films more accessible, films whose total production is about one third of all those made.

In the card files of biological films it would be worthwhile to indicate those useful for different types of postgraduate study, to issue a list of scientific and university films suitable for this purpose and to consistently collect and utilize films from the field of biology in postgraduate courses. These problems were discussed e.g. in 1964 at a conference on educational films in Moscow, that discussed the theory and production of educational films and at the conclave on technical and botanical films held during the III Festival of Scientific and Technical Films in Budapest in 1964.

Finally, let us review the advantages of disseminating biological information through the film as an educational method. As a kind of permanent record, the biological film can be used at any time and anywhere for study and analytical use. It can be re-used many times over, in similar conditions and at similar times. It can be produced in many copies for simultaneous use or in TV as a mass means of communication. It is suitable for demonstrating and evaluating slow and undiscernible processes and a combination of techniques permits an objective analysis. It perfects observation, in that it eliminates all subjective or emotional reactions, and guides the audience towards scientific observation. It permits a permanent record and repetition of processes that are unique and cannot be repeated. When available in a film library it can serve as study and documentary material on the present state and development of biological science.

In biology as in the other sciences, the value of cinematography has been recognized particularly in the bordering branches. The application of the approach and methods of work of one branch to another has proven very effective and often leads to nontraditional and surprising interpretations of results or to new problems and methods of research. In this lies the importance of films from special biological fields, as for example the field of ecology, on which Professor E. Buchsbaum of Pittsburg is working in collaboration with five countries. These will be short films made according to a pre-arranged project of 68 problems.

That is why international cooperation was set up in 1958 to deal with a series of scientific films, and as from 1960, systems of exchange and cooperation were created in the field of cinematography, specially tailored to the needs of a certain scientific sector. In this respect it would be suitable to ascertain at scientific biological institutes the current state of apparatus technique and research tasks solved by film, or whether films on similar themes have been produced anywhere else. The newly established world film library of scientific films in Brussels enables the on-the-spot study of these biological films sent to that library. The International Scientific Film Association (ISFA) then has the task of presenting information on the experience gained during the shooting of the biological films.

As in the section on scientific research films, the films are shown to experts at international festivals held by this organisation. They are asked to approve the objectivity and correctness of the explanation of the processes recorded in the film. The magazine "Scientific Film" publishes experience during the filming and the construction and adaptation of apparatus.

At the present time the ISFA is preparing an analysis called "How to organise the introduction of films for teaching biology and other sciences", which is to be supplemented by takes from different film techniques in a feature of ten short films. This research will also contribute to the greater use of biological films in training. No doubt this information is nothing new to those who are themselves creators of biological films, however, we think it will be worthwhile for the information of new scientific workers interested in the method of research and instruction.

IV. SOURCES OF INFORMATION ON BIOLOGICAL FILMS

In the first days of collecting "cultural films", as they were called, there were difficulties with classifying and cataloging this type of films.

The American Congress Library has been registering films since 1890. There was no clause at the time on the registration of motion pictures, so all films were classified as photographs. Today several methods of classification are in use. In 1956 UNESCO issued a proposal in which a total of 17 different types of films for instruction and information were mentioned. For a university teacher wanting to use the film the procedure according to content is decisive. His primary interest is what field of science is available. Secondly, he looks to see what level of instruction the film is meant for, not only the likely level use, but the more closely specified demands in view of the curriculum and text-books. In this connection practice too is varied. The film files of the World Mineralogical Society have films for six different levels of education, instruction films for 10 different levels, while the Atomic Energy Centre lists a total of films for 22 different levels of knowledge in this field. The teacher is also interested in learning the technique used in making a particular film.

Stipulating the category is therefore not typical for the use of film and it is often artificial and hitherto incomplete. This data, however, should be obtained through an analysis of actual films, not from the descriptive and written reports on films.

Recently, the situation has improved, for scientific film bulletins are being published centrally, as well as magazines and publications from which one can learn of the number of biological films and their division into the individual science disciplines.

If the biological film is to become an important part of publishing and disseminating scientific knowledge, it should also be expertly described. As a result there has been a big demand that scientists making the films write up the "résumé, and possibly provide the translations into different languages, so that the quality of information is not lost through defective translations. This demand is obvious also from the approach to shooting the films. If today, the science of sciences analyse - for example - the scientific principles governing the setting up of experiments - we can equally examine the problem of how the scientific film originates.

Insufficient knowledge of film creation and accessibility to it, which has been slowly improving with the setting up of international science film libraries prevent, even before the actual shooting of a film begins, a showing of all films already made on a similar theme with a review of the script, the selection of objects, expert collaboration, conditions of time and the location of filming.

The methods of film making, the lighting, shooting technique, length of the shots, type of pictures and their evaluation, are not apparent from the filmographic description and often not even from the pictures. The use of biological films also demands a knowledge of the commentary and conclusions or summary of the results, the method of using control pictures for comparing or evaluating the takes.

Into the required description of biological films we can also list the technical operations and calculations, the determining of the ratio of time and of scale, scientific supervision of the film by a scientists and screening of the quality of the standard copy (proper color, tone) etc.

The classifying of biology films simplifies the looking up of a needed film. It is easily carried out in instances where the authors themselves prescribe what aim the film must attain in special scientific research. However, despite this classification, as shown by experience from Padua or from the catalogue of biology films issued in Warsaw, characterising the films is not unambiguous; therefore all the more reason why there should be a "résumé" by the author. By classifying the film in a certain category or level of instruction, as mentioned in 1932 by B. Groombridge, applied to biology films, shows the seriousness of these problems.

We can use biology films in higher scientific technological instruction or information, for courses in biological disciplines, as a program on the development of biological science. Other films can serve for demonstration purposes in biological laboratories or experimental proce-

dures while didactic biology films can demonstrate and illustrate lectures on biology. This division permits a more accurate stipulation of the aim of biology films and defines the type suitable to the audience.

On the whole, the evaluation of biology films today corresponds to the situation in the evaluation of science films generally. It is carried out either at science film festivals or at organised showings for experts and possibly for compiling a catalogue later. The least developed is the evaluation of biology films on the basis of their investigation. As a result there is no connection between the incidence of biology films and the conception of new films, nor in the influence of research in elaborating new biological films. With the growing number of biology films these problems will increase. This was first shown in the pilot studies made at the initiative of ISFA in 1963-1965, particularly in the conflict between the actual and possible degree of utilisation of science films, in the quality of films at our disposal and in the number of films from the individual branches of science. In biology, research was carried out in 70 biological films, which is 33 % of the total number of films from 6 branches of science. Films from other branches included chemistry 23 %, physics 30 %, geology 6 %, mathematics 4 %, medicine 4 %.

Let us see how the number of science films on biology has grown in the catalogue of the Institut für den Wissenschaftlichen Film in Göttingen. From May 1966 to May 1967 there was an increase of 87 films on zoology, 8 microbiology films, 1 cytology film, 1 botanical film. In 1965, out of a total of 854 films, this film library had 427 biology films, that is one half.

The actual number of biology films cannot be precisely estimated. It is only from the film productions in individual countries, or from the structure of the festivals over several years, that we can get an idea of the number of films in the individual branches of science in the field of biology, one of the largest film categories. University biologists are most interested in the special catalogues of biological films. UNESCO's documentation from 1955 however, does not list a single special catalogue of biology films, even the 1963 list of catalogues does not mention biology film catalogues. Only in 1965 did the Association Polonaise du Cinéma Scientifique issue a catalogue of biology films but announced that the received data was incomplete and apologized for the omission of an index of articles and names. To be able to compile a detailed and filmographically complete list of films from the field of biology, it would be necessary to assemble the films on the basis of evaluation and not written reports on them or description of films made in the individual countries.

At the present, world organisation centres are collecting data from national societies and organisations of science films and research institutes in the respective branches of science. This has already been done in compiling a list of films from the field of very low temperatures. The films are classified according to the scientific grading of the special branches, with an accurate differentiation of films dealing with basic scientific problems and those documenting the application of the branch of science in practice. Film libraries are today being set up in all the general libraries of various international scientific organisations; the film catalogues

gues being compiled by library or documentary personal in the individual scientific centres.

For a summary of the individual types of biology films we present, in conclusion, several tables :

Table 1.- From the catalogue of biological films we can see the branches of science represented and the number of films made in various countries according to specialization.

Country origin of film	G.D.R.	G.F.R.	Australia	Bulgaria	Canada	France	Britain	Holland	Israel	Poland	Rumania	CSSR ⁺⁺	Uruguay	USSR	Total
Science branch of biology															
General Biology	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1
Molecular biol.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Genetics-developp	5	42	2	1	6	14	-	5	-	8	1	4	-	-	88
Animal Physiol.	8	-	-	2	3	15	-	8	2	9	2	3	11	5	68
Plant Physiol.	1	-	-	-	3	4	-	1	-	9	-	-	-	2	20
Zoology	9	49	-	-	6	19	-	-	-	7	-	1	9	-	100
Botany	-	35	-	-	1	1	-	1	-	4	1	-	1	-	44
Hydrobiology	-	-	-	-	1	1	-	-	-	1	2	-	-	-	5
Entomology	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Microbiology	-	-	-	-	1	-	-	1	-	-	-	1	-	1	4
Virology	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Parasitology	-	-	-	-	-	2	1	-	-	-	-	1	3	-	7
Biophysics	-	-	-	-	4	2	-	1	-	3	-	2	-	3	15
Biochemistry	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anthropology	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ecology	6	-	1	-	5	2	-	-	-	31	2	-	6	1	54
Biological Tech.	-	-	1	-	1	3	-	3	-	3	-	1	-	4	16
Agrobiology	-	-	-	-	-	-	-	-	-	-	3	-	-	3	6
Total	29	126	4	3	32	63	1	20	2	75	11	13	30	19/ + 98	428

Note : + USSR lists a further 98 popular science films from the field of biology.

++ Only the popular science films are mentioned.

Table 2.- In the analysis of films from the field of biology in the last five years shown at reviews in Padua we are able to document the number of biological films and countries producing them and compare the number with films from other branches of science. (VI-XI Rassegna internazionale del film Scientifico-Didattico 1962-1966).

Country of Origin Biology films I. Category	year					Total
	1962	1963	1964	1965	1966	
USA	-	1	-	1	2	4
Belgium	-	-	-	-	-	-
Japan	1	-	-	1	-	2
Holland	-	1	-	1	-	2
France	2	1	5	2	3	13
Israel	1	-	-	-	-	1
Italy	4	1	-	1	-	6
GDR	1	1	-	-	-	2
Australia	-	1	1	-	-	2
Poland	-	1	-	-	-	1
Britain	-	-	-	1	-	1
Hungary	-	-	-	-	-	-
Switzerland	-	-	-	1	-	1
Rumania	-	-	-	-	-	-
Total 1962-1966 science I. category	9	7	6	8	5	35

Branch of Science	year					Total
	1962	1963	1964	1965	1966	
Biology, scientific and didactic	16	21	13	15	13	78
Physics, Mathematics, Chemistry	19	25	18	19	15	96
Medicine - surgery	20	20	26	14	17	97

Table 3.- From data obtained in a British film catalogue we present the number of biological films in the years 1965-1966 according to specialisation.

(Additions of biology films in the British National Film Catalogue)

year Science branch	1965	1966	Notes
General Biology	9	2	Additions DS :
Molecular Biology	-	-	57 Biology
Genetics	84	10	57 Anthropology
Animal Physiology	2	-	58 Botany
Plant Physiology	1	-	59 Zoology
Zoology	8	46	
Botany	5	9	
Hydrology	-	-	
Entomology	-	-	
Microbiology	12	1	
Virology	1	-	
Parasitology	1	-	
Biophysics, Biochem.	12	-	
Anthropology	2	3	
Ecology	23	21	
Biology technique	10	-	
Animal Biology	1	1	
Embryology	2	3	
Total	173	96	

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Le rôle du film dans l'enseignement de la biologie et l'information scientifique

F. Ledvinka
(Résumé)

Le film est un moyen très approprié pour la communication et la propagation des connaissances biologiques. Il complète ou remplace les méthodes d'observation directe et d'analyse scientifique des phénomènes, il est capable d'englober une grande quantité d'informations qu'il est possible d'évaluer au fur et à mesure mathématiquement. La mesure de l'adéquation de la communication picturale des métamorphoses suivies d'objets et d'actions a une grande importance dans la popularisation de la biologie, elle facilite la communication sur le niveau scientifique sur les différents degrés de l'éducation. Etant donné que le film scientifique biologique peut résumer à un niveau très élevé les connaissances biologiques, il constitue un moyen d'enseignement de la biologie au plus haut niveau d'éducation ainsi que de l'enseignement post scolaire des professeurs de biologie.

Pour pouvoir exploiter à fond le film dans la biologie il est nécessaire d'assurer une parfaite technique cinématographique de prises de vue et de former les spécialistes pour son exploitation. D'autre part, il faut élaborer les méthodes d'emploi du film sur les différents degrés d'écoles, assurer le commentaire détaillé du film et l'explication de la méthode de communication cinématographique. La technique cinématographique des institutions les plus avancées peut être utilisée dans la coopération internationale.

Les réserves actuelles de films biologiques ne correspondent pas à l'état actuel et à l'évolution de la science. Certains domaines ne sont pas traités, il y a des différences dans l'emploi de la technique cinématographique dans différents Etats. Le désir de spécialisation se heurte au désir de producteurs indépendants d'exploiter au maximum le film. Ce fait abaisse la valeur éducative des films qui apportent trop d'informations.

Il faut, d'une part, attirer l'intérêt des savants sur le film biologique, les renseigner sur les films biologiques déjà existants qui peuvent être employés plus intensivement au cours de l'enseignement de la biologie et compléter, d'autre part, avec leur aide les fonds mondiaux par d'autres films qui contiendraient les informations de base sur l'état de la science biologique pour les besoins de l'enseignement supérieur où ils peuvent garantir le niveau atteint de la science et cela même là où cette science n'est pas assez développée.

C'est aux cinémathèques de films scientifiques appartenant aux institutions nationales qu'incombe à présent la tâche d'informer sur les films biologiques existants ainsi que l'Association internationale de la cinématographie scientifique ISFA qui édite des catalogues internationaux de films scientifiques.

Il faudra penser également à la conception de films nécessaires pour la popularisation de la biologie par rapport à leur émission dans les programmes de télévision et à l'avenir dans les programmes de satellites.

La función del cine en la enseñanza de la biología
y la información científica

F. Ledvinka

(Resumen)

El cine es un medio muy apropiado para la comunicación y la propagación de los conocimientos biológicos. Completa o sustituye a los métodos de observación directa y de análisis científico de los fenómenos y es capaz de englobar una gran cantidad de información que puede evaluarse sucesivamente por procedimientos matemáticos. La posibilidad de medir la eficacia de la comunicación visual de metamorfosis continuas de objetos y de acciones tiene una gran importancia en la divulgación de la biología y facilita la comunicación en el nivel científico y en los diferentes grados de la enseñanza. Puesto que el cine científico biológico puede resumir en un nivel muy elevado los conocimientos biológicos, constituye un medio de enseñanza de la biología en el nivel más alto de la educación así como de la enseñanza postescolar de los profesores de biología.

Para poder explotar a fondo el cine en la biología es necesario aplicar una perfecta técnica de registro cinematográfico y formar especialistas para su explotación. Por otra parte, hay que preparar métodos de empleo del cine en los diferentes grados de la enseñanza, así como el comentario detallado de cada película y la explicación del método de comunicación cinematográfica. La técnica cinematográfica de las instituciones más avanzadas puede utilizarse en la cooperación internacional.

Las reservas actuales de películas biológicas no corresponden al estado presente ni a la evolución de la ciencia. Ciertos dominios quedan excluidos y hay diferencias en el empleo de la técnica cinematográfica en los distintos Estados. El deseo de especialización tropieza con el afán de los productores independientes de explotar al máximo cada película. Esto reduce el valor educativo de las películas que aportan demasiada información.

Por una parte, hay que suscitar el interés de los hombres de ciencia por el cine biológico e informarles sobre las películas biológicas ya existentes que pueden emplearse más intensivamente en el curso de la enseñanza de la biología y, por otra, completar con su ayuda los fondos mundiales con otras películas que contengan informaciones fundamentales sobre el estado de la ciencia biológica para las necesidades de la enseñanza superior en la que pueden reflejar el nivel alcanzado por la ciencia precisamente donde ésta no se encuentra lo bastante desarrollada.

La tarea de informar sobre las películas biológicas existentes incumbe actualmente a las cinematecas de películas científicas dependientes de las instituciones nacionales así como a la Asociación Internacional de Cinematografía Científica (AICC), que edita catálogos internacionales de películas científicas.

Habrá también que pensar en la realización de las películas necesarias para la divulgación de la biología mediante su emisión en los programas de televisión y, más adelante, en los programas transmitidos por satélites.

A PROPOS DE L'ENSEIGNEMENT PROGRAMMÉ

par Annick NOËL (Lycée Lakanal)

On parle beaucoup, depuis quelques années, d'enseignement programmé et de machines à enseigner. Un grand nombre d'entre nous se demandent quelle est exactement la signification de ces expressions et de quelle valeur sont cette méthode et ce procédé pour notre discipline. M^{me} A. Noël, qui a participé à un stage sur l'enseignement programmé à l'Institut Pédagogique National, répond ici à ces questions.

Est-ce une nouvelle méthode d'enseignement ? Pas exactement, car on ne trouve rien de nouveau dans les principes qui caractérisent l'Enseignement programmé et qui sont essentiellement :

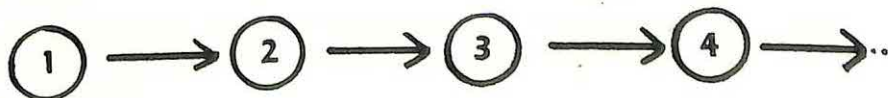
- le découpage d'une leçon en nombreuses étapes ;
- la participation active de l'élève, sollicitée par de nombreuses questions auxquelles il doit répondre avant d'avancer dans son étude ;
- le contrôle immédiat de la réponse, qui constitue un encouragement à la poursuite de l'étude. La présentation de la réponse (on insiste sur ce qui doit être su) permet un effet de renforcement, très important selon les psychologues.

Chaque enseignant applique ces principes dans la mesure du possible, et l'Enseignement programmé est encore moins une révolution si l'on pense que le dialogue élève-maître établi par le jeu des questions et des réponses se rencontre déjà dans Platon (dialogues socratiques) et que Descartes, dans le **Discours de la Méthode**, préconise la pulvérisation de l'information en petites unités ; il propose en effet « de diviser chacune des difficultés en autant de parcelles qu'il serait requis pour les mieux comprendre ».

Alors, qu'y a-t-il de nouveau ? C'est le souci d'une application systématique de ces principes à la construction d'un programme (ce mot vient de la cybernétique où il désigne l'ensemble des ordres donnés à la machine dans le but d'en obtenir un comportement donné). Ce programme doit permettre l'acquisition très progressive des connaissances. La façon de rédiger un programme est donc tout à fait déterminante quant à l'efficacité de cette méthode. On distingue deux types essentiels :

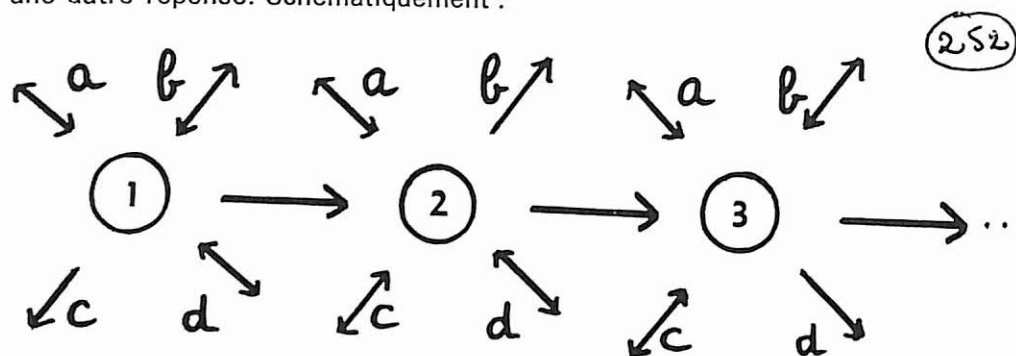
Les programmes linéaires (type Skinner).

Chaque unité du programme comprend une information et une question. La bonne réponse est habilement soufflée à l'élève qui l'écrit, la vérifie et passe à la question suivante, selon le schéma :



Les programmes ramifiés (type Crowder).

Plusieurs réponses sont proposées ; l'élève doit effectuer un choix. S'il s'est trompé, il trouve l'explication de son erreur et il est prié de choisir une autre réponse. Schématiquement :



Dans certains cas, l'erreur entraîne l'élève vers une voie secondaire ou il trouve un supplément d'information. Contrairement à Skinner, Crowder pense que l'erreur est tolérable et qu'elle est même utile.

Comment sont présentés les programmes ? Voilà une question séduisante pour les éditeurs et les constructeurs de machines ! 90 % des programmes actuels sont sur papier : fiches ou livres. La présentation la plus originale est celle des livres brouillés (scrambled books) qui contiennent des programmes ramifiés. Comme une flore, un tel livre ne se lit pas dans l'ordre normal de la pagination. Il y a aussi les fameuses machines à enseigner dont le côté spectaculaire contribue à faire connaître l'Enseignement programmé. Ces machines, pourtant, ne méritent pas vraiment leur nom, car c'est le programme qu'elles présentent qui apprend quelque chose. Elles semblent pouvoir rendre de grands services, car elles permettent une présentation agréable du programme, facilitant le recensement des erreurs, et surtout suppriment les tentatives de fraude, toujours possibles avec un livre : l'utilisateur de la machine ne voit apparaître sur un écran la deuxième question que dans la mesure où il a bien répondu à la première.

Qui s'intéresse à l'Enseignement programmé ?

En France, surtout :

- l'Institut Pédagogique National (journées d'études, stages, séminaire continu) ;
- le Centre audio-visuel de l'Ecole Normale Supérieure de Saint-Cloud ;
- l'Association de Pédagogie cybernétique ;
- le Centre d'Etudes et d'Instruction psychologique de l'Armée de l'Air.

A l'étranger, les recherches sont très avancées aux Etats-Unis, en U.R.S.S., en Grande-Bretagne. L'UNESCO a organisé des stages d'information en Afrique (Nigéria, Ethiopie, Madagascar) et au Brésil.

Quelles sont les disciplines intéressées ? Toutes, dans la mesure où l'on ne peut rejeter en bloc toutes les suggestions apportées par l'Enseignement programmé.

Les Mathématiques et les langues (maternelle et étrangères) sont les disciplines les mieux représentées jusqu'ici.

Et nous ? Les services que nous pouvons attendre de l'Enseignement programmé sont peut-être modestes, mais peut-on vraiment en décider ainsi sans avoir essayé ?

L'observation doit pouvoir être dirigée par un programme, et chaque élève pourrait ainsi adopter le rythme qui lui conviendrait. Remarquons aussi que la machine à enseigner peut présenter des séquences de films ou des photos.

La rédaction d'un programme pose de nombreux problèmes. Il faut déterminer de façon très précise les objectifs du programme (quel doit être le comportement terminal de l'élève ?) ; il faut rechercher un enchaînement logique des idées-clés, diviser la matière de la leçon en nombreuses séquences. Les contrôles expérimentaux, indispensables, entraînent toujours des retouches. En Sciences naturelles, en Physique-Chimie et en Technologie, se pose de plus le problème de la place de l'observation et de l'expérience par rapport au programme.

Et si les essais nous montrent que finalement l'utilisation d'un programme n'est pas souhaitable pour l'enseignement de la Biologie ? Alors l'Enseignement programmé n'aura été que l'occasion pour certains d'entre nous d'une réflexion sur les méthodes de l'apprentissage, et peut-être aura-t-il permis d'améliorer le cours normal lui-même.

Certains des problèmes que nous nous posons, par exemple la recherche des moyens permettant la participation effective de tous les élèves à l'observation menée en classe, semblent pouvoir être abordés par le biais de l'Enseignement programmé.

Deviendrons-nous des « chefs d'atelier », guidant nos élèves installés devant le clavier de leur machine ? La perspective est déroutante... mais pas sombre, une classe travaillant avec un programme est une classe qui reste très vivante. « C'est plus vivant », ont même déclaré mes élèves enthousiastes, après un premier essai (très modeste, avec des feuilles photocopiées). Certains ont regretté d'être « obligés de travailler ». Il vaut mieux écouter tranquillement un cours »... Voilà la conclusion de l'un d'eux.

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EXEMPLES DE PROGRAMMES

I. — Extrait d'un **programme linéaire** sur les Mammifères (classe de sixième) :

1. Le Chat a un squelette osseux dont la partie la plus importante est la colonne Le Chat appartient à l'embranchement des Vertébrés.

(Donnez votre réponse en remplaçant les points par le mot qui convient ; vérifiez ensuite votre réponse page X ; si elle est exacte, passez à la question suivante.)

2. Le Lapin, qui a un squelette osseux, appartient à l'embranchement des

(Remplacez les points par le mot qui convient ; vérifiez ensuite votre réponse page Y ; si elle est exacte, passez à la question suivante.)

3. Tous les Mammifères ont un squelette osseux, ce sont des

(Donnez votre réponse, vérifiez-la ensuite page Z ; si votre réponse est exacte, passez à la question suivante.)

N.B. — Les réponses aux questions successives se trouvent, bien entendu, à des pages différentes afin que l'élève ne risque pas de rencontrer des réponses à l'avance.

II. — Extrait d'un **programme ramifié** sur la génétique (classes terminales).

P. 7. — Aux quatre groupes sanguins correspondent six génotypes :

AA et AO pour le groupe A
BB et BO pour le groupe B
AB pour le groupe AB
OO pour le groupe O

Le gène A et le gène B dominant le gène O, mais il n'y a pas de dominance de A sur B ni de B sur A.

Voici un exercice : M. et M^{me} Durand ont quatre enfants. François est du groupe A, Claude du groupe B, Dominique du groupe O, Gérard du groupe AB. Que pouvez-vous dire au sujet des groupes sanguins de M. et M^{me} Durand ?

Si votre réponse est :

- | | |
|--|-------------------------|
| — Groupe AB tous les deux..... | Reportez-vous à la page |
| — L'un groupe A, l'autre B | 5 |
| — L'un groupe O, l'autre AB | 9 |
| — Vous pensez qu'il est impossible que les enfants issus d'un même mariage soient de quatre groupes différents | 12 |
| — A votre avis, on ne peut rien dire de précis sur les groupes sanguins des parents, car il y a plusieurs possibilités | 14 |
| | 15 |

P. 5 (venant de la page 7) :

Inexact ! Votre réponse serait admise... s'il n'y avait pas Dominique !
Voyons en effet ce que donne le croisement AB × AB.

		Gamètes de la mère	
		50 % A	50 % B
Gamètes du père	50 % A	AA	AB
	50 % B	BA	BB

Soit : 25 % de la descendance : groupe A
50 % — groupe AB
25 % — groupe B

Retournez donc page 7, repensez le problème et choisissez une autre réponse.

P. 9 (venant de la page 7) :

Oui, c'est la bonne réponse, mais vérifions que vous ne l'avez pas trouvée par hasard. Vous devez être capable de préciser le génotype des parents.

Réponse :	Reportez-vous page
AA et BB	6
AO et BB	10
AA et BO	13
AO et BO	16

P. 12 (venant de la page 7) :

Pas du tout. Les deux génotypes des parents seraient alors OO et AB et par conséquent les deux possibilités de groupes sanguins pour les enfants sont A et B (génotypes AO et BO) ; vous voyez donc que vous n'avez pas expliqué ainsi les groupes de Gérard et de Dominique ! Retournez page 7 ; pour ne pas risquer un autre échec, réfléchissez bien et trouvez la bonne réponse.

P. 14 (venant de la page 7) :

Mauvaise réponse. Prenez donc un crayon et du papier et recherchez quelle peut être la descendance d'un couple dont vous connaissez les deux groupes sanguins, $AA \times OO$, $AB \times OO$ par exemple. Prendre ainsi le problème à l'envers sera un bon exercice. Retournez ensuite page 7 et ne manquez pas la bonne réponse.

P. 15 (venant de la page 7) :

Réponse inexacte. Vous vous êtes sans doute exercé, en considérant les génotypes, à rechercher le résultat de quelques croisements (sinon faites-le vite !), mais vous avez mal travaillé. Refaites ce travail d'approche avec plus d'attention, puis retournez page 7 pour y choisir la bonne réponse

P. 6 (venant de la page 9) :

Mais non ! Les gamètes du parent de groupe A porteraient tous alors le gène A, ceux du parent de groupe B porteraient tous le gène B... Une seule possibilité d'union : AB. Retournez page 9.

P. 10 (venant de la page 9) :

Mauvaise réponse. En effet :

		Gamètes du parent AO	
		50 % A	50 % O
Gamètes du parent BB...	B	AB	BO
	Enfants	50 % AB	50 % B

Retournez page 9.

P. 13 (venant de la page 9) :

Non. On n'explique pas ainsi les groupes sanguins de Claude et Dominique. En effet :

		Gamètes du parent BO	
		50 % B	50 % O
Gamètes du parent AA...	A	AB	AO
Enfants		50 % AB	50 % A

Retournez page 9.

P. 16 (venant de la page 9) :

Votre réponse est exacte. En effet :

		Gamètes du parent AO	
		50 % A	50 % O
Gamètes du parent BO...	50 % B	AB	BO
	50 % O	AO	OO

Interprétons ce tableau :

- 25 % des enfants..... groupe AB
- 25 % des enfants..... groupe B
- 25 % des enfants..... groupe A
- 25 % des enfants..... groupe O

Les quatre enfants Durand schématisent donc bien ce résultat. Veuillez tourner la page.

Sur la page suivante, le lecteur trouvera l'unité suivante du programme.

Annick NOËL.

A propósito de la enseñanza programada

A. Noel

(Resumen)

La enseñanza programada consiste en la división de una lección en numerosas etapas, la participación activa del alumno solicitada mediante numerosas preguntas y la verificación inmediata de la respuesta, que constituye un incentivo para la prosecución del estudio. El autor describe varios esquemas posibles y da indicaciones prácticas sobre los problemas planteados, no todos los cuales están resueltos. En un anexo figuran dos ejemplos de programas, uno lineal (primera clase de la enseñanza secundaria) y otro ramificado (clase terminal).

Programmed instruction

A. Noel

(Summary)

Programmed instruction consists of the breaking down of a lesson into a number of stages, active pupil participation stimulated by a series of questions, and the immediate verification of each response, which is an encouragement to proceed with the lesson. The author describes various possible patterns and gives practical indications of the problems set, of which only some are solved. Annexed are two examples of programmes, one linear (for the first year of secondary education), and the other ramified (terminal class).

UNE CONCEPTION DES SUJETS D'EXAMEN

S. Bozzone

(Lycée Janson-de-Sailly, Paris)

... Me demandant pourquoi tant de belles instructions restaient sans effets pratiques sur la réalité des résultats généraux constatés dans l'enseignement du second degré, je me suis convaincu, il y a longtemps déjà, que la forme et le contenu de tout enseignement se modèlent sur la nature de l'examen qui le sanctionne. Si l'examen demande avant tout de prouver une mémorisation la plus complète possible, c'est vers cet effort de mémoire, insensé dans son volume et combien précaire dans ses résultats, que s'orienteront les élèves, parfois en dépit des efforts opposés de leurs maîtres. Et combien de maîtres cèdent eux-mêmes à cette sollicitation dans le but d'aider dans l'immédiat leurs élèves à obtenir un diplôme, oubliant, face à ce leurre, que leur rôle est de préparer les hommes et femmes du XXI^e siècle.

Proposez aux examens des sujets qui obligent l'élève à justifier d'une aptitude déterminée et les maîtres se sentiront tous à l'aise en choisissant des compositions dans le même esprit après avoir enseigné dans ce but. Que doivent être de tels sujets d'examen si l'on se propose de demander au candidat la preuve autant de ses aptitudes que de ses connaissances ? Ce sont des suggestions à ce propos qui vont suivre, fruit de quinze ans d'essais dans mon enseignement des Sciences naturelles et des expériences de quelques collègues.

Je me rends bien compte de tout ce que la présentation analytique qui suit des aspects de la formation intellectuelle aura d'artificiel. Mais n'est-ce pas le propre de l'analyse de « détruire » l'unité d'un corps, pour arriver à la comprendre et à la reconstituer ? N'est-ce pas en pensant à chacun des aspects partiels de la culture, en s'obligeant à les inculquer séparément, en vérifiant non moins séparément d'abord leur acquisition et le degré de maîtrise atteint que nous aurons plus de chance d'arriver à un résultat cohérent. Devant le large échec qui caractérise pour moi les résultats de notre enseignement du second degré, je pense que c'est par cet effort de formation analytique (soutenu par le contrôle correspondant) que nous créerons davantage de chances de former plus de « têtes bien faites ».

On ne peut se passer de connaissances, c'est-à-dire de notre mémoire. Plus celle-ci est amplement pourvue, vive, fidèle, plus les autres aptitudes intellectuelles jouent à l'aise et efficacement. Il est même possible par sa seule mémoire de faire illusion sur sa propre personnalité. Ces truismes ne doivent point être oubliés sous peine de tomber d'un excès dans un autre. **Notre enseignement doit continuer à développer et à meubler largement la mémoire, mais peut-être d'une façon plus intelligente qu'on ne le constate souvent.** Qu'est-ce à dire ?

Il faut faire apprendre des mots, le plus de mots possible. Les études faites à ce sujet ont montré l'indigence extraordinaire du vocabulaire moyen. Mais connaître un mot est tout autre chose que la connaissance de sa graphie et de sa phonie. Si j'appelle vocabulaire « concret » celui dont les mots désignent des objets matériels, un mot est connu lorsque son expression écrite ou sonore fait naître dans la conscience l'image correspondante et réciproquement ; toute l'image sinon une série d'images pour peu qu'on s'arrête à les chercher. Plus ces images « internes » sont nombreuses, meilleure est la connaissance de l'objet.

Notre enseignement se devrait de vérifier d'abord cette connaissance des mots utilisés par les élèves, d'enrichir ces mots d'images nouvelles, d'augmenter le nombre de mots connus. En effet, la méconnaissance des êtres vivants en particulier s'accroît catastrophiquement avec l'urbanisation et ce, malgré les progrès des moyens audiovisuels qui pourraient y suppléer. On connaît le *Platycerium* que l'on cultive avec amour, l'*Asparagus* des bouquets, mais en fin de semaine on ne reconnaît pas l'Asperge dans le jardin, dans les champs cultivés toute Graminée est du Blé, dans les prés, c'est de « l'herbe » dans laquelle il y a des « bestioles ».

Combien d'exercices de reconnaissance à vue fait-on depuis l'enseignement élémentaire jusqu'au baccalauréat sur objet réel ou sur photo ? Quant à l'art de communiquer aux élèves un amour suffisant de la nature, les amener à faire ce travail personnellement, il faut avouer qu'il est rare.

Un tel exercice de reconnaissance à vue, facile à organiser à l'oral, n'est pas impossible à introduire même au cours d'une épreuve écrite d'examen, comme dans une composition trimestrielle. Par exemple, chaque candidat prend 5 minutes sur son temps pour passer devant 10 échantillons (réels ou photographie) et note en même temps ses résultats sur une feuille qui est jointe à sa copie en fin d'épreuve. Il suffirait qu'une liste des objets à connaître soit publiée ; elle n'est pas impossible à établir. Les échantillons présentés à la reconnaissance pourraient être différents d'un groupe de candidats à l'autre, puisque tous les objets présentés sont censés être connus. Il me semble, par ailleurs, que 5 minutes effectives

d'exercices sur ce sujet à chaque leçon de Zoologie et Botanique de la sixième à la classe terminale devraient permettre d'assimiler une somme respectable de végétaux et animaux.

A côté du vocabulaire « concret », plaçons le vocabulaire « abstrait » ou mieux la connaissance « abstraite » de tout vocabulaire.

J'appellerai ainsi la connaissance du mot telle que nous la fournissent les dictionnaires, c'est-à-dire la définition du mot sous ses divers sens. On reste effaré devant le nombre de termes (aussi bien les plus courants que ceux un peu spécialisés des diverses disciplines) pour lesquels les élèves sont incapables de donner une définition. Qu'un enfant de six ans soit capable d'appeler « chaise » des chaises diverses et ne se trompe pas avec un tabouret quand on lui en demande une, nous le trouvons normal ; normal aussi qu'il ne sache pas donner une définition abstraite de la chaise ; de la part d'un bachelier, ce n'est pas acceptable.

Et ne cherchez pas à savoir ce qu'est une force, une digestion, pour prendre deux des termes qui, avec température et chaleur, sont employés journellement de la façon la plus incohérente.

Cette connaissance abstraite du vocabulaire rejoint en Biologie et probablement dans toutes les Sciences expérimentales la connaissance des idées fondamentales. Savoir réciter une **définition** de terme comme digestion, respiration, aliment, vitamine, Mammifère, Champignon, etc., n'est peut-être pas suffisant pour faire la preuve d'une compréhension profonde des faits, mais c'est tout de même une étape indispensable. Si je pense que ces définitions a posteriori devraient le plus souvent être introduites comme conclusion synthétique d'études analytiques basées sur l'examen des faits, je crois non moins fermement à la nécessité d'en **exiger la mémorisation la plus parfaite possible**. Nous n'obtiendrons cet effort de la part des élèves qu'en introduisant de telles questions tant dans leurs compositions qu'aux examens. Si les définitions sont connues, la récitation de quelques-unes ne demandera qu'un temps très court. Reste le problème de savoir quelle définition on demandera d'un même terme aux niveaux successifs de l'enseignement. Le principe devrait être que tous les termes contenus dans la définition soient eux-mêmes connus. Par exemple, à un niveau élémentaire, on devrait se contenter de définir la digestion par : **« On appelle digestion l'ensemble des transformations, surtout chimiques, subies par les aliments en présence des sucs digestifs. Ces transformations ont en particulier pour effet de solubiliser les aliments solides et aboutissent à des corps qui peuvent traverser la paroi de l'intestin. »** Une telle définition pose plus de questions qu'elle n'en résout. N'est-ce pas le propre de tout progrès de la connaissance ? N'est-ce pas en refusant de satisfaire totalement la curiosité qu'on l'entretient ?

Plus tard, au niveau B.T.A. (Sc. Ex.), on arriverait par exemple à : **« On appelle digestion l'ensemble des phénomènes, surtout chimiques, qui rendent les aliments assimilables. Ils consistent essentiellement en simplifications moléculaires par réactions d'hydrolyse catalysées par des enzymes plus ou moins spécifiques. Ces hydrolyses conservent la spécificité chimique fondamentale et font disparaître la spécificité biologique ; du point de vue physique, elles aboutissent le plus souvent à des corps en solution vraie. »**

Pour mon compte, je désirerais qu'un bachelier, un T.A., sache d'abord cela et ensuite seulement un peu du détail des transformations locales et

des enzymes. Demandons-lui donc de faire d'abord cette preuve et nous aurons augmenté les chances pour que, comme nos grand-mères qui savent encore leurs départements, sous-préfectures comprises, nos bacheliers et T.A. n'oublient pas les idées fondamentales sur la digestion.

Il faut noter que des « définitions » comme celle citée sur la digestion n'ont rien d'absolu dans leur forme ni dans les limites de leur contenu. Pour l'instant, c'est au professeur de les créer. Leur systématisation qui n'est pas réalisée serait pourtant utile et à des niveaux différents. Elle aiderait beaucoup les débutants et les maîtres non spécialistes de l'enseignement élémentaire ; elle éviterait certaines erreurs de niveau sinon de fond.

Parmi les méthodes de vérification des connaissances acquises, il est bon de s'arrêter un peu sur celle des « Questions à choix multiple » (Q.C.M.). Cette technique d'examen (appelée test de connaissances dans l'enseignement élémentaire) est pratiquée depuis quelques années en Médecine et vient d'être introduite en 1965 à la première partie du professorat d'Education physique. Il en est donné les principes et quelques exemples en annexe .

Conduit à la faire pratiquer par obligation familiale, puis professionnelle directe, je l'ai abordée avec prévention. Actuellement, je lui reconnais de nombreux mérites que je résume ainsi :

— vérification rapide de la sûreté des connaissances au niveau que le rédacteur des questions détermine avec précision ;

— possibilité en un temps court (de 1 à 2 mn par question) d'étaler les questions sur l'ensemble du programme et d'empêcher toute « impasse » payante ;

— possibilité de jugement des aptitudes foncières lorsqu'on utilise tous les types de questions :

- aptitude à la lecture assimilée de questions où, souvent, aucun mot ne peut être négligé ;
- rapidité de réflexion, sang-froid devant un choix difficile en un temps très court ;
- aptitude à la mobilisation de connaissances apprises en ordre dispersé ;
- aptitude à passer rapidement d'un mode de réflexion à un autre (les divers types de question).

Il y a là un ensemble qui permet de juger la mémorisation des faits et bien d'autres qualités intrinsèques des candidats. Peut-être devrions-nous essayer d'introduire ces interrogations par Q.C.M. dans certaines compositions ; peut-être même dans les examens mais pas exclusivement. En effet, cette technique présente la très grave lacune de ne faire appel comme moyen d'expression qu'à la possibilité de tracer une croix, ce que réussissent même les illettrés totaux.

Savoir s'exprimer avec le maximum de précision est non seulement un aspect de la culture, mais la nécessité fondamentale des relations humaines. En ce domaine, en France, le français doit être roi. Insistons sur la nécessité cruciale pour chaque professeur de chaque discipline d'être autant professeur de français que de sa spécialité, c'est-à-dire d'exiger un usage rigoureux de notre langue écrite et parlée, de juger une réponse non d'après ce qu'il croit que l'élève a voulu dire, mais d'après le sens

réel de ce qui est prononcé ou écrit. L'habitude des maîtres d'aller au-devant des réponses d'élèves, de chercher la lueur de compréhension à travers l'incorrection de la forme est certes fort louable à certains égards, mais elle remplace l'effort de l'élève par celui du maître ; elle ne crée pas chez le premier le sentiment que seule une expression correcte et précise de sa propre pensée a quelque chance d'être valablement reçue par l'interlocuteur. Soyons intransigeants sur ce point, en classe d'abord, aux examens ensuite : les élèves feront l'effort demandé.

L'homme cultivé ne peut plus se contenter de sa seule langue maternelle, il lui faut être apte à utiliser beaucoup d'autres formes de langage : le schéma avec sa forme très rationalisée qu'est le dessin industriel, le symbolisme mathématique des fonctions, des lois physiques et leur forme graphique, le symbolisme chimique, etc. La connaissance de l'alphabet et de la syntaxe de tous ces langages fait partie de la culture moderne de tout homme, quelle que soit sa spécialisation, ainsi que l'aptitude à traduire de l'un à l'autre.

C'est un aspect de l'enseignement des Sciences expérimentales (surtout), c'est une des aptitudes dont les examens devraient vérifier l'acquisition. Voici, par exemple, quelques types de sujets d'examen possibles :

- Le sujet est une description d'un montage expérimental, la réponse demandée est un schéma cohérent avec le texte — ou l'exercice inverse (voir en exemple le sujet n° 2 en annexe).
- Le sujet est le tableau de grandeurs réellement mesurées au cours d'une expérience, l'exercice est de tracer la courbe représentative des rapports entre deux grandeurs étudiées (qui ne sont pas toujours celles directement mesurées) (voir sujet 1).
- Le sujet est la courbe représentative d'un phénomène en fonction d'un autre, l'exercice est d'exprimer les rapports entre ces grandeurs, soit d'une façon qualitative (langage courant), soit d'une façon mathématique (voir sujet n° 8).

Ces types d'exercices peuvent évidemment être conjugués entre eux.

POUR AVOIR UN SENS RÉEL, CHACUN DE CES EXERCICES DE « VERSION » DESTINÉ A APPRÉCIER NON UNE CONNAISSANCE PARTICULIÈRE MAIS LA CONNAISSANCE D'UN LANGAGE ET L'APTITUDE A TRADUIRE EN UN AUTRE DEVRAIT A L'EXAMEN PORTER SUR UN SUJET CHOISI HORS DU PROGRAMME SI POSSIBLE EN PROLONGEMENT OU EN RAPPORT AVEC UNE DES QUESTIONS ÉTUDIÉES.

Qui lit les programmes de Sciences et leurs instructions (de l'enseignement élémentaire et du second degré) ne manque d'être frappé par la place donnée à l'observation. On s'attendrait donc à ce qu'un élève de sixième soit initié, qu'un élève de seconde soit déjà rompu, qu'un bachelier soit maître de cet aspect du travail intellectuel. Que de déceptions successives ! Je n'expliquerai pas les causes de cette situation et ne démontrerai non plus l'importance de cette formation à l'observation par la variété des qualités intellectuelles dont il faut savoir user.

Il suffira de rappeler que si l'observation nécessite d'abord un **effort méthodique d'analyse**, c'est pour aboutir à des choix, des comparaisons, une compréhension abstraite synthétique de l'objet ou du phénomène, et même conduit à poser des problèmes.

Me retiendront davantage la nécessité de contrôler l'aptitude à l'observation personnelle et les moyens utilisables aux examens.

Si l'examen comporte un oral (ce qui est toujours éminemment souhaitable), c'est là qu'il faut placer un exercice d'observation, car il est facile de proposer des sujets de toutes natures : aussi bien des objets réels, des expériences que des reproductions photographiques. C'est là que pourrait se placer aussi un exercice d'utilisation de flore ou de faune qui correspond à une observation dirigée mais très précise. Il est possible ainsi, sous forme orale, d'imaginer bien des formes à cet exercice d'observation, mais toutes devraient correspondre aux critères suivants :

— le sujet à observer devrait n'avoir qu'une chance infime d'avoir déjà été étudié ; seules interviendraient la mémoire générale et la méthode de pensée :

— l'examineur n'intervient pas du tout. Il se contente d'écouter et de regarder. Le but du contrôle me paraît être d'apprécier les qualités strictement personnelles du candidat, celles qui lui seront directement nécessaires et utiles dans sa vie et non pas son aptitude à réagir à des sollicitations plus ou moins précises. Par exemple, à un niveau très élémentaire, le candidat doit penser à définir les formes sans qu'on ait besoin de le lui demander.

Si l'on désire placer un exercice d'observation à l'écrit, l'objet à étudier ne pourra probablement pendant longtemps encore n'être que la **reproduction imprimée d'une ou plusieurs vues photographiques de l'objet**. Cette limitation des possibilités ne devrait pas suffire à exclure cet exercice quand on songe à la place que tient l'image photographique, fixe ou animée, dans notre vie actuelle. De même, le problème de la fourniture des documents aux candidats me paraît un faux problème face aux moyens de reproduction en grande série dont dispose notre époque.

L'histoire des Sciences biologiques nous apprend que, si une partie de leurs progrès est liée à celui des techniques, elles n'ont acquis leur titre de Sciences que lorsque, à défaut de mesures exactes, elles ont mis au point une méthodologie rigoureuse, c'est-à-dire qu'ont été précisées les **méthodes de démonstration, de raisonnement** dans le va-et-vient constant entre la pensée abstraite et les faits. Une initiation à cette méthodologie des Sciences biologiques qui est actuellement au point dans bien des domaines, très variée dans le détail, très nuancée dans ses applications, me paraît être capable de donner à l'esprit toutes les chances d'atteindre à un équilibre entre l'esprit de géométrie et l'esprit de finesse, que beaucoup croient encore pouvoir obtenir par la seule formation gréco-latine. Encore faut-il que l'enseignement de la Biologie se propose cette initiation. Reconnaissons que, jusqu'à présent, et ce malgré les vœux formulés par certains, c'est vers la mémorisation des résultats acquis qu'il s'est surtout orienté sans assez se préoccuper de leur **mode d'obtention et de leur degré de validité**.

Là encore, c'est l'introduction de « **problèmes biologiques** » aux examens qui infléchiront l'enseignement. La maigre part faite à la Biologie même dans les derniers projets de réforme de l'Enseignement du Second Degré tient à l'opinion encore courante « qu'en Sciences naturelles il n'y a qu'à apprendre ».

De même que dans un problème de mathématiques nous demandons le plus souvent à l'élève de reconstituer le cheminement logique entre une hypothèse et une conclusion fournies, nous pouvons proposer comme sujet de montrer pourquoi et dans quelle mesure un fait biologique (d'observation ou expérimental) prouve ou suggère telle interprétation. Comme en

mathématique, tous les niveaux sont possibles. Comme en mathématique toujours, **le sujet d'examen doit être choisi hors des questions traitées en classe.**

En résumé, une épreuve d'examen (de Biologie en particulier) se devrait de permettre au candidat de faire preuve des qualités suivantes :

- connaissances générales ;
- aptitude à utiliser avec précision les divers modes d'expression et à passer de l'un à l'autre ;
- aptitude à l'analyse, au choix, à la comparaison, à la synthèse ;
- connaissance des grands principes de méthodologie et aptitude à s'en servir.

Evidemment, toutes ces qualités peuvent être mises en relief dans l'exposé d'un sujet de Biologie de style classique, mais combien de candidats sont-ils persuadés que c'est cela que l'on attend d'eux, bien plus que la récitation d'un cours ou d'un manuel. Puisque ce type de sujet encourage en fait le bête et éphémère bachotage, il nous faudrait en changer. Je suis absolument convaincu de l'efficacité qu'auraient des épreuves composées sur les principes suivants :

1. L'épreuve comporte **une partie contrôle des connaissances et une partie contrôle des diverses aptitudes.** Le nombre des points affecté à chaque partie est indiqué dans le texte. Si l'égalité me paraît souhaitable, on pourrait aussi, surtout pendant une période transitoire d'adaptation de l'enseignement, laisser une certaine prépondérance aux connaissances. Les expériences effectuées en composition m'ont aussi montré l'utilité de préciser le temps qu'il était conseillé d'affecter à chaque aspect de l'épreuve.

2. La partie mémoire devrait être conçue de façon à obliger **l'expression des connaissances générales.** Bien des procédés sont possibles, plus ou moins valables suivant le niveau de l'examen allant d'une série de questions précises, telles que définitions, listes de propriétés, énoncés de lois, de caractères généraux, etc., jusqu'à la rédaction de l'ensemble des idées fondamentales d'un vaste sujet.

Peut-être même pourrait-on envisager de scinder cette partie en deux :

- une série de Q.C.M. (20 par exemple en 20 mn) qui contrôlèrent la variété et un certain niveau de connaissances ;

- une question à rédiger (20 mn) qui, ne devant être que la récitation d'idées sues, ne doit pas demander de temps de réflexion.

3. A la partie **« vérification des aptitudes »** qui oblige à cette réflexion devrait être consacrée de l'ordre des 2/3 du temps (1 h 20 sur 2 h).

Son organisation peut être conçue soit comme une série d'exercices sur des sujets différents (chaque exercice portant sur une des aptitudes précédemment définies) soit comme une progression de questions sur un même sujet. **Le fond des questions porterait sur des points pris hors des programmes,** mais si possible en prolongement de ceux-ci. Dans tous les cas, les **éléments nécessaires à la solution seraient fournis,** y compris une large partie de ceux dont la connaissance pourrait être supposée acquise.

En appendice, vous trouverez quelques exemples de sujets qui ont été effectivement donnés en composition dans des classes de première et de Sciences expérimentales. Ils ne répondent pas tous aux critères précédents, mais certains datent de déjà pas mal d'années. Ils donnent tout de même

une idée concrète de ce que pourraient être des sujets d'examen de ce type.

Une objection qui ne manque jamais d'être faite, c'est que ce genre d'épreuve est beaucoup plus difficile, que si nos élèves ne réussissent déjà pas à apprendre, ils réussiront encore moins à comprendre. Il est certain que de tels sujets donnés à la plupart des élèves actuels provoquent le désarroi et des résultats catastrophiques. Il n'en a jamais été de même avec mes élèves (et ceux de mes collègues) qui étaient, par le style de l'enseignement, préparés à cette forme. Que cela demande à l'élève un effort spécial, d'un autre ordre, c'est certain, mais beaucoup finissent (même en une seule année) par préférer cette forme de travail.

Présentée dès 1958, sous forme de vœu, par l'Union des Naturalistes, l'idée d'introduire un « problème » dans les compositions de Sciences naturelles du baccalauréat a reçu l'approbation verbale des autorités, mais jamais un commencement d'exécution. Reviendra-t-il au jeune enseignement agricole le mérite de rompre avec une tradition préjudiciable à la place de la Biologie dans la formation de l'homme du XX^e siècle ?

APPENDICE

A. — Exemples de sujets de composition donnés en classes de Première M' et Sciences expérimentales

SUJET 1. — Durée : 2 heures.

Question 1 (notée sur 10).

— Énoncez la définition et les propriétés essentielles des diastases.

— Sous quelle forme se trouvent les principaux types d'aliments à la fin de la digestion et quels caractères généraux peut-on trouver aux transformations subies ?

— Donnez une définition de la digestion.

Question 2 (notée sur 10).

Avec l'appareil utilisé en classe pour démontrer la réaction réversible $\text{Hb} + \text{O}_2 \rightleftharpoons \text{HbO}_2$, un de vos camarades a réalisé les mesures suivantes :

Ayant introduit de l'oxygène, il a attendu chaque fois, avant de lire la pression, que celle-ci reste constante. A ce moment, il a prélevé 2 cm³ de la solution d'hémoglobine et il a dosé la quantité totale d'oxygène qui pouvait se dégager de la solution.

Il a obtenu le tableau de nombres suivant :

Pression de O ₂ en mm de Hg.	0	4	12	26	38	62	74	88	106	760
Volume de O ₂ libéré.....	0	8	13	29	36	38	539	540	41,5	42
par 2 cm ³ de solution d'hémoglobine (en 1/100 mm ³)										

En admettant que pour la pression 760 mm d'oxygène toute l'hémoglobine (soit 100 %) est à l'état d'oxyhémoglobine (HbO₂), établissez la courbe représentative du pourcentage de HbO₂ dans une solution d'hémoglobine, en fonction de la pression de l'oxygène au-dessus de la solution.

Soit d'après le tableau de chiffres, soit d'après la courbe, comparez l'influence d'une variation de pression de l'oxygène à partir de 20 mm et de 90 mm de Hg.

Sujet 2. — Durée : 2 heures.

Première partie (durée prévue : 1 heure), 10 points.

Conservation et dégradation de l'énergie. (Il n'est attendu comme développement qu'environ ce qui peut se recopier en 15-20 mn).

Deuxième partie. — MÉTHODE CALORIMÉTRIQUE DE BUNSEN.

A) Description de l'appareil (4 points).

— L'appareil est d'abord constitué par une enceinte métallique A où est introduit le corps qui prend (ou fournit) la quantité de chaleur à mesurer. A se complète d'un bouchon très isolant B.

— A plonge dans une enceinte C étanche et entièrement remplie d'eau au-dessus d'une faible épaisseur de mercure.

— De la base de C part un tube D qui remonte verticalement près de C et se termine par un petit réservoir ouvert. Ce réservoir qui, comme D, contient du mercure, peut être coupé de D par un robinet R.

— En dessous de R, le tube D. porte un tube capillaire E de section interne environ $1/10 \text{ mm}^2$ ouvert à son extrémité et dont la plus grande partie est horizontale.

— C, D et R sont plongés dans un bac qui contient un mélange d'eau et de glace.

Faites un schéma cohérent de l'appareil.

Veillez, entre autres, à ce que les échanges de chaleur du corps introduit en A ne puissent se faire directement qu'avec l'eau de C.

B) Principe de l'utilisation.

1. Préparation du calorimètre (3 points).

a) On introduit en A un corps sec X porté à -15° dans un mélange réfrigérant glace-chlorure de sodium.

Que se passe-t-il dans l'ensemble A-C ?

b) On sort X. En conjuguant des inclinaisons de l'appareil et la manipulation de R, on amène l'extrémité du mercure du tube E à une position que l'on repère : soit 1_0 .

Que pensez-vous de l'évolution ultérieure du mercure dans E en fonction du temps ?

La température du laboratoire est supposée ne varier que $\pm 2^\circ$.

2. Utilisation (3 points).

a) On introduit dans A un corps Y à la température $t^\circ \neq 0$.

Que prévoyez-vous comme évolution du système ?

b) Montrez comment cette évolution peut servir à mesurer des quantités de chaleur.

SUJET 3. — Durée : 2 heures.

QUESTION 1 (6 points). — Définition, sens physiologique général, intérêt de : « **intensité** » et « **quotient** » respiratoires.

QUESTION 2 (6 points). — Donnez, sans les développer, les idées fondamentales actuelles sur le mécanisme essentiel des oxydations cellulaires.

QUESTION 3. — Une rate pesant 18,5 g est enfermée pendant 25 minutes dans une enceinte contenant 1050 cm^3 d'air à 18° . Au bout de ce temps, du gaz est prélevé pour être analysé par la méthode à l'acide pyrogallique et la potasse. Les manipulations réalisées à la température de 18° donnent les résultats successifs suivants :

$V_1 = 48,8 \text{ cm}^3$; $V_2 = 46,6 \text{ cm}^3$; $V_3 = 38,5 \text{ cm}^3$, avec une incertitude de $\neq 0,1 \text{ cm}^3$ sur chaque lecture.

(On admettra que la pression atmosphérique était normale.)

2 points — 2 — Rappelez le **principe de la méthode** d'analyse employée.

4 points — B — Calculez l'intensité respiratoire de cette rate en milligrammes d'oxygène par heure et par kilogramme. Veillez à ne donner que le nombre de chiffres significatifs compatible avec les incertitudes de mesure.

2 points — C — Calculez le quotient respiratoire de cette rate et dites ce qu'il vous apprend.

SUJET 4. — Durée : 3 heures.

QUESTION 1 (notée sur 4).

Définissez : **osmose, dialyse, floculation.**

Comment concevez-vous une molécule de protéide (ou protéine) ?

QUESTION 2 (notée sur 2).

Quelle propriété chimique commune connaissez-vous à l'amidon (polysaccharide) et à l'albumine (protéide) ?

QUESTION 3 (notée 4).

Classez, selon l'ordre d'importance décroissante que vous leur attribuez, les faits que vous avez retenus sur la mitose.

QUESTION 4 (notée sur 10).

Nous vous rappelons les faits suivants que vous avez vus en travaux pratiques sur les fragments d'épiderme d'oignon mis à tremper dans une solution de rouge neutre dans du Ringer.

1. Dans certaines cellules, la vacuole seule est colorée en rouge orangé. Les granulations du cytoplasme sont en mouvement.

2. Dans d'autres cellules (en général moins nombreuses), ce sont le cytoplasme et le noyau qui sont colorés en rouge. Les granulations du cytoplasme sont immobiles.

3. La teinte rouge orangé de la vacuole est plus accentuée que celle de la solution de rouge neutre qui a été utilisée pour le montage et qui est vue à peu près sous la même épaisseur.

4. Quelques vacuoles sont colorées en violet.

5. En remplaçant le « Ringer » du montage par une solution à 20 % de glucose, on voit peu à peu le volume de la vacuole diminuer et le cytoplasme se décoller de la membrane cellulosique.

6. En mettant le fragment précédent dans l'eau, la vacuole de la plupart des cellules augmente de volume et on retrouve l'état initial.

7. Avec quelques morceaux d'épiderme, les phénomènes précédents n'ont pu être observés qu'en prenant une solution de glucose plus concentrée.

En utilisant en particulier les connaissances de physique et de chimie étudiées en classe, interprétez les résultats précédents et dites quelles connaissances ils vous apportent sur les cellules de cet épiderme d'Oignon. Veuillez, dans votre rédaction et présentation, à séparer les idées successives.

NOTA.

1. Les faits rappelés dans l'énoncé sont ceux que j'avais demandés aux élèves de découvrir (observer) en 1 h 1/2 de travail rigoureusement personnel à partir de leurs propres préparations extemporanées réalisées à partir d'une fiche de travail.

Pendant ce temps, j'avais uniquement contrôlé que chaque montage était valable, c'est-à-dire permettait d'y lire les faits pour lesquels je l'avais choisi.

Dans la dernière demi-heure de la séance, la correction générale avait permis à chaque élève de vérifier l'existence des phénomènes qu'il n'avait pas su voir tout seul.

2. Dans une leçon précédente sur la mesure de l'acidité vraie d'un milieu (pH), j'avais apporté la notion de variété des « indicateurs colorés ».

3. Les élèves avaient été invités à préparer l'interprétation des faits constatés. Ceci devrait lever une objection possible touchant au rapport longueur du sujet - temps disponible.

SUJET 5. — Durée : 2 heures.

QUESTION I (4 points). — Définir : **osmose, dialyse, solution, floculation.**

QUESTION II (6 points). — Montrer à quelle conception de l'état colloïdal conduisent le phénomène de dialyse et l'effet Tyndall. (Inutile de décrire ces phénomènes.)

QUESTION III (6 points). — Dans le phénomène dit d'électrophorèse, nous avons créé un champ électrique entre une électrode positive cylindrique et une électrode négative plate plongée dans une solution de rouge congo à 0,5 g par litre.

Nous avons constaté :

— un éclaircissement de la solution le long de l'électrode plate, c'est-à-dire un changement de valeur de la teinte ;

— un nuage bleu se développant à partir de l'électrode cylindrique. L'examen précis de cette électrode montre la présence de particules solides ;

— entre les deux électrodes, la solution restait identique à elle-même ;

— en agitant les électrodes, la solution reprenait son aspect initial ; en particulier, les grains de solide bleu disparaissaient.

(Le dégagement gazeux observé peut être éliminé en réglant convenablement la différence de potentiel entre les électrodes. Il est dû à l'électrolyse des ions carbonates obligatoirement présents dans la solution.)

1° Interpréter en justifiant : l'éclaircissement le long de l'électrode plate ; le dépôt de solide sur l'électrode cylindrique.

2° Que pouvez-vous conclure du comportement du rouge congo dans un champ électrique et de son état dans la solution ?

QUESTION IV (4 points). — Que résume-t-on lorsqu'on dit que le cytoplasme a les propriétés physiques d'un gel colloïdal ?

Nota. — L'expérience évoquée par la question III avait été réalisée en fin de leçon deux jours avant. Les faits observables avaient été notés et les élèves invités à préparer l'interprétation.

SUJET 6. — Durée : 2 heures.

1. La théorie chromosomique de l'hérédité et les faits essentiels sur lesquels elle s'appuie (14 points).

2. Les groupes sanguins des systèmes ABO et Rhésus sont héréditaires et suivent les lois de Mendel avec O récessif par rapport à A et B ; A et B équivalents ; Rh + dominant.

Soit une Mère A, Rh + qui donne naissance à un enfant O, Rh —.

a) Quel est le génotype de l'enfant ?

b) Quel est le génotype de la mère ?

c) Quel a été le génotype du gamète mâle qui a assuré la fécondation ?

d) Quels phénotypes masculins sont possibles ?

e) Quelles sont les incompatibilités paternelles ?

SUJET 7. — Durée : 3 heures.

Les élèves disposent des planches de schémas : allures du Cheval, allures du Chien.

QUESTION 1. — En utilisant la méthode employée en classe, analysez les allures du Cheval d'après la planche de schémas que vous possédez.

Vous n'avez à rédiger que les caractères généraux (tirés de l'analyse) qui peuvent servir de définition à chaque allure. Vous justifierez chacun de ces caractères par le numéro du schéma (ou le groupe de numéros) où il est lisible.

Nota. — Vous êtes tenu, si vous en avez besoin dans la rédaction, d'adopter comme numérotage des membres celui qui figure sur le schéma de la marche du Cheval.

Notation : marche 2, trot 2, galop 4.

QUESTION 2. — Comparez les allures du Cheval à celles du Chien. Vous pouvez utiliser la planche de schémas des allures du Chien.

Notation : marche 2, trot 1, galop 3.

QUESTION 3. — Que désignent chez l'Homme et l'Escargot les termes de tête, cou, pied ?

Comment justifiez-vous cette identité de vocabulaire ?

Quel intérêt et quel danger y voyez-vous ?

SUJET 8. — Durée : 2 heures (extrait du Bulletin de l'U.d.N.).

Pour mesurer la vitesse de l'influx nerveux, le physiologiste Paul BERT pratiquait pendant son cours (en 1880) à peu près l'expérience suivante :

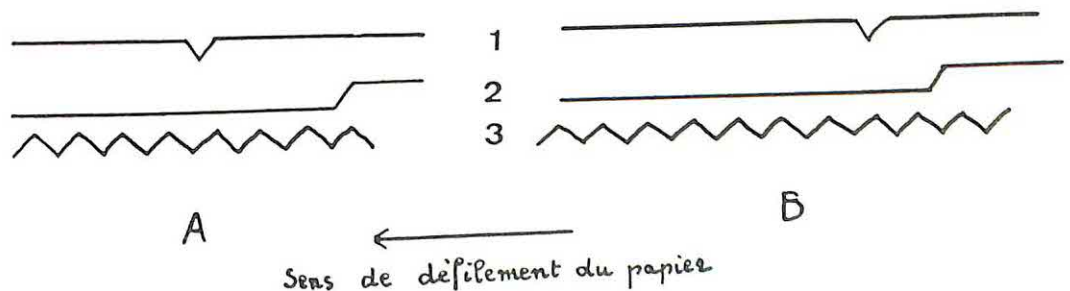
Sur le papier enfumé d'un cylindre, un stylet (1) inscrivait l'instant où une décharge électrique était envoyée à deux électrodes voisines de 1 mm. Un stylet (2) était relié à un levier manipulé par le sujet. Un stylet (3) inscrivait les vibrations d'un diapason de fréquence 125 hertz.

L'enregistrement A correspond à une excitation portée à l'extrémité des doigts de la main gauche du sujet. Dès perception de l'excitation, le sujet manipule le levier du stylet (2).

L'enregistrement B correspond à l'expérience similaire, l'excitation étant portée à l'épaule du sujet qui, dans les deux cas, ne voit pas opérer l'aide.

On vous demande :

- 1) d'expliquer les enregistrements A et B ;
- 2) d'évaluer la vitesse de l'influx nerveux sachant que les deux points du corps excités successivement sont distants de 65 cm, le résultat obtenu vous paraît-il d'un ordre de grandeur acceptable ?
- 3) Vous avez étudié en classe une autre méthode de mesure de la vitesse de l'influx nerveux. Décrivez-la. Dites laquelle des deux méthodes vous paraît la meilleure et pourquoi ?



B. — Exemples de questions à choix multiple

(Extrait de la notice à l'usage des étudiants en Médecine
publiée par le Ministère de l'Education nationale)

1. LE TYPE DE QUESTION LE PLUS FRÉQUEMMENT UTILISÉ EST APPELÉ « A COMPLÉMENT SIMPLE »

a) Réponse correcte.

L'exemple suivant est de ce type.

QUESTION 1.

Parmi les caractères suivants, indiquer **celui** qui s'applique à tous les enzymes :

- A) Ils contiennent toujours un coenzyme dissociable ;
- B) Ils sont thermostables ;
- C) Ils contiennent toujours de l'azote dans leur molécule ;
- D) Ils contiennent toujours du phosphore dans leur molécule ;
- E) Ils sont dialysables.

La réponse étant C, la même question peut être rendue un peu plus difficile en omettant d'indiquer la réponse exacte parmi les choix proposés et en la remplaçant par le choix suivant : « Aucune des réponses précédentes n'est exacte ».

QUESTION 2.

Parmi les caractères suivants, indiquer **celui** qui s'applique à tous les enzymes :

- A) Ils contiennent toujours un coenzyme dissociable ;
- B) Ils sont thermostables ;
- C) Ils contiennent toujours du phosphore dans leur molécule ;
- D) Ils sont dialysables ;
- E) Aucune des réponses précédentes n'est exacte.

De nouveau, utilisons la question précédente et offrons les choix suivants :

QUESTION 3.

- A) Ils contiennent toujours un coenzyme dissociable ;
- B) Ils sont thermostables ;
- C) Ils contiennent toujours de l'azote dans leur molécule ;
- D) Ils sont dialysables ;
- E) Aucune des réponses précédentes n'est exacte.

Dans cette version, la mention « aucune des réponses précédentes n'est exacte » est incorrecte et la réponse correcte devient C.

b) Choisir la réponse incorrecte.

QUESTION 4.

Un hydrosol métallique a tous les caractères suivants **sauf un**.

Indiquer **lequel** :

- A) Peut être formé par l'arc électrique ;
- B) Est toujours coloré ou trouble ;
- C) Peut dialyser ;
- D) Peut être floculé par une trace d'électrolyte ;
- E) Possède toujours une charge électrique.

2. TYPE « ASSOCIATION SIMPLE »

Des questions d'un type quelque peu différent peuvent être utilisées d'une manière efficace pour s'assurer de la connaissance d'un certain nombre d'entités qui peuvent être ou ne pas être en relation. Ce type consiste en une liste précédée d'une lettre suivie par une liste de mots ou phrases précédés d'un numéro. Pour chacun des mots ou phrases précédés d'un numéro, le candidat doit faire la sélection d'une phrase précédée d'une lettre qui soit particulièrement associée.

QUESTIONS 5 à 9.

Branche postérieure du nerf radial :

- A) Le segment d'origine (tiers supérieur) ;
- B) Le groupe des rameaux postérieurs ;
- C) Le groupe des rameaux antérieurs ;
- D) Le nerf interosseux postérieur.

Question 5 : est appliqué sur la face postérieure du ligament interosseux sur une partie de son trajet.

Question 6 : contourne le col du radius.

Question 7 : innerve les muscles de la couche superficielle de la région antibrachiale postérieure.

Question 8 : passe entre les deux chefs du court supinateur.

Question 9 : innerve les muscles de la couche profonde de la région antibrachiale postérieure.

3. TYPE « ASSOCIATION COMPOSÉE »

Soit deux propositions A et B.

Le candidat reçoit les instructions de répondre A si la question numérotée est associée seulement avec A.

Répondre B si la question est associée seulement avec B.

Répondre C si la question est associée à la fois avec A et B.

Répondre D si la question n'est associée ni avec A ni avec B.

QUESTIONS 10 à 14.

Exemple. — Les examens suivants :

- A) Syndrome cérébelleux ;
- B) Syndrome tabétique ;
- C) Les deux à la fois ;
- D) Aucun des deux.

Question 10 : Ataxie.

Question 11 : Nystagmus.

Question 12 : Dissociation des sensibilités.

Question 13 : Signe de Babinski.

Question 14 : Douleurs fulgurantes dans les membres inférieurs.

4. TYPE « ASSOCIATION A TERME EXCLU »

Ce type de question est employé plus rarement. Il est beaucoup plus élaboré, appelant une compréhension discriminative d'un certain nombre de facteurs similaires.

Instructions : 4 des 5 propositions de la liste numérotée sont communes à l'une des 3 de la liste précédée de lettres.

Indiquer la proposition précédée d'une lettre qui est commune à 4 des propositions numérotées **et** la proposition numérotée qui est l'exception.

QUESTIONS 15 et 16.

A) Matité thoracique.

B) Souffle tubaire.

C) Râles sous-crépitants :

1° Pneumonie ;

2° Atélectasie ;

3° Dilatation des bronches ;

4° Infiltration néoplasique de la plèvre ;

5° Pleurésie tuberculeuse.

Nous rappelons que pour ce type de question le candidat doit donner deux réponses (la question vaut ainsi deux points).

Ainsi, pour cette question, la réponse correcte est A-3, c'est-à-dire que l'on trouve une matité thoracique dans **tous** les syndromes indiqués de 1 à 5, sauf dans la dilatation des bronches.

5. TYPE « RELATION DE CAUSE A EFFET »

Un type de question spécialement applicable à certains des aspects les plus cachés de la médecine est l'analyse de relation de cause à effet. Dans les situations présentées dans ce type de question, la réponse correcte ne peut être obtenue que par un bon raisonnement et une compréhension des principes de base inclus dans le problème. Ce type de question consiste en une phrase comprenant deux parties principales : une constatation et une raison pour cette constatation. Le candidat doit répondre :

A - si la constatation et la raison proposées sont toutes les deux vraies et qu'il existe une relation de cause à effet entre les deux ;

B - si la constatation et la raison proposées sont toutes les deux vraies et qu'il n'y a pas de relation de cause à effet entre elles ;

C - si la constatation est vraie mais la raison proposée est fausse ;

D - si la constatation est fausse mais si la raison proposée est un fait ou un principe accepté ;

E - si la constatation et la raison proposées sont toutes les deux fausses.

QUESTIONS 17 à 20.

Question 17. — L'articulation radio-cubitale supérieure permet des mouvements limités de rotation **parce que** la tête du radius est entourée par le ligament annulaire.

Question 18. — Les ligaments latéraux du genou sont relâchés dans les mouvements de flexion **parce que** les condyles du fémur ont un rayon de courbure décroissant d'avant en arrière.

Question 19. — Le muscle biceps brachial est innervé par le nerf médian **parce que** ce nerf innerve la plupart des muscles fléchisseurs.

Question 20. — Le sinus coronaire présente une valvule terminale **parce que** toutes les veines qui débouchent dans l'oreillette droite ont une valvule terminale.

6. TYPE « COMPARAISON QUANTITATIVE »

Instructions : les paires d'énoncés suivantes décrivent deux entités qui doivent être comparées quantitativement. Sur la feuille de réponse, remplissez l'espace sous A si X est plus grand que Y, sous B si Y est plus grand que X, sous C si les deux sont égaux ou très proches.

Question 21.

X - Pression mécanique dans le capillaire veineux.

Y - pression oncotique dans le capillaire veineux.

Question 22.

X - Normalité d'une solution de soude à 40 g/litre.

Y - Normalité d'une solution de HCl à 36,5 g/litre.

7. TYPE « VARIATION ET RELATION »

Instructions : chacune des paires énoncées suivantes décrivent des conditions ou des quantités qui peuvent être ou ne pas être en relation. Sur la feuille de réponse, remplir l'espace correspondant à :

A - si l'augmentation du premier est accompagnée d'une augmentation du second ou si la diminution du premier est accompagnée d'une diminution du second ;

B - si l'augmentation du premier est accompagnée d'une diminution du second ou si la diminution du premier est accompagnée d'une augmentation du second ;

C - si les variations du second sont indépendantes des variations du premier.

Question 23.

1° Le débit circulatoire cutané.

2° La quantité de chaleur perdue par unité de temps.

Question 24.

1° La pression veineuse.

2° Le remplissage diastolique du cœur.

Question 25.

1° La valeur de la pression artérielle.

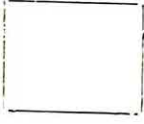
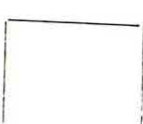
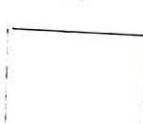
2° La fréquence des potentiels d'action dans le nerf de Hering.

8. TYPES « A COMPLÉMENTS GROUPÉS »

Instructions : pour chacun des exposés incomplets suivants, **un** ou **plusieurs** des compléments proposés sont corrects. Répondre lequel ou lesquels parmi les compléments sont corrects et remplir l'espace correspondant sur la feuille de réponse :

- A - si seulement les compléments 1, 2 et 3 sont corrects ;
- B - si seulement 1 et 3 sont corrects ;
- C - si seulement 2 et 4 sont corrects ;
- D - si seulement 4 est correct ;
- E - si un autre complément (ou groupe de compléments) autres que ceux indiqués en A, B, C ou D sont corrects.

RÉSUMÉ DES INSTRUCTIONS

A	B	C	D	E
				
1, 2 et 3 seulement	1, 2 seulement	2, 4 seulement	4 seulement	un autre choix

Question 26.

Cinq conscrits mesurent : 1,65 m, 1,67 m, 1,69 m, 1,63 m, 1,61 m.

- 1° La moyenne des tailles de l'échantillon est de 1,65 m.
- 2° L'écart type est proche de 8.
- 3° L'écart type est proche de 2,8.
- 4° L'échantillon a de bonnes chances de renseigner, sur la population, des tailles des individus en général.

Question 27.

L'amplitude de la pointe (spike) du potentiel d'action d'une fibre nerveuse unique est :

- 1° proportionnelle à l'intensité de l'excitant ;
- 2° nulle quand l'intensité de l'excitant est inférieure à une valeur seuil ;
- 3° variable le long de la fibre ;
- 4° constante quelle que soit l'intensité de l'excitant lorsque celle-ci est supérieure au seuil.

9. SCHÉMAS, PHOTOGRAPHIES, COURBES, etc.

Des diagrammes, des graphiques ou des photographies peuvent être utilisés afin de sonder la connaissance d'une structure, d'une fonction, du **cours d'un état clinique** ou d'un classement statistique. Des questions peuvent être alors demandées afin de désigner les éléments d'un schéma.

Una concepción de los temas de examen

S. Bozzone

(Resumen)

El artículo enfoca el problema de los exámenes en función de la finalidad de la enseñanza secundaria. Teniendo en cuenta que esta última debe continuar desarrollando y poblando en gran medida la memoria, el autor muestra cómo puede concebirse una memorización inteligente a partir de definiciones adaptadas y regular su adquisición. Se examina con bastante detenimiento el método de las "preguntas de respuestas múltiples" y se analizan sus ventajas y sus inconvenientes. Se proponen ejercicios nuevos tales como la traducción de un fenómeno biológico en una de las formas del lenguaje científico: simbolismo matemático, simbolismo de las leyes físicas, dibujo, etc. Se insiste en la necesidad de comprobar la adquisición de los métodos de demostración y de razonamiento y de apreciar las aptitudes mediante "problemas biológicos" planteados a los alumnos. En un apéndice se dan varios ejemplos de esos temas.

Ideas for examination subjects

S. Bozzone

(Summary)

The article considers the problem of examinations in the light of the purpose of secondary education. Bearing in mind the need to continue to develop and expand the memory, which should be well-stocked with information, the author expounds a system for intelligent memorizing based on adapted definitions, and shows how its acquisition can be verified. He deals at some length with the method of "multiple-choice questions", analysing its advantages and disadvantages. He suggests new exercises such as the expression of a biological phenomenon in terms of one of the languages of science: mathematical symbolism, the symbolism of physical laws, drawings, etc. He insists on the need to verify the acquisition of methods of demonstrating and reasoning, and to assess ability by "biological problems" set as tests for the pupils. An appendix gives several examples of the kind of subjects envisaged.

Section 4 / Partie 4

LOCAL DEVELOPMENTS / REALISATIONS LOCALES

New Developments in Elementary School Biology

- John D. Cunningham, *Science Curriculum Improvement Study, University of California, Berkeley, and Florida State University, Tallahassee*

Presented at the NABT meetings with the AAAS in Berkeley, December, 1965, this paper describes various major projects dealing with biology at the elementary school level. The author is Associate Professor of Science Education.

Because the biological element in most of the current elementary school science projects is just beginning to develop, it is difficult to do more than briefly identify and describe the several groups. Like most of the secondary school projects, these elementary programs are generally financed by the NSF. Unlike the secondary projects, however, the elementary groups do not, in general, want to produce separate programs in biology, chemistry, physics, and the earth sciences but, instead, aim to produce a sequence of activities that will familiarize the child with science *per se*. Some projects are producing an articulated sequence of topics, others interesting investigations for children that pedagogues can use at the level they see fit.

None of the emerging biological programs is understandable apart from the trend in elementary school science itself. Some projects aim to introduce the child to certain intellectual "inventions" found useful by man in his history for interpreting natural phenomena (e.g., SCIS, MINNEMAST) while others do the same for man's useful "processes" of investigating the world (e.g., AAAS). Still others are developing investigations into biological phenomena that are more open-ended and that include both of the above elements (e.g., ESS). Brief descriptions are given below of selected projects.

Science Curriculum Improvement Study

The SCIS is developing an articulated sequence of studies for children between kindergarten and grade six. The Study wants, from the earliest levels, to increase the child's awareness of the diversity, dynamism, and complexity of living systems. The program is based heavily upon observation and direct involvement by children and, therefore, be-

gins with such observables as the typical patterns of the growth, development, and behavior of organisms.

One of the striking but confusing aspects of the study of organisms is the variability encountered. The "Harvard Law of Animal Behavior" is based on just such variability. Variation may be so extreme as to appear random and the discovery of the typical patterns of the growth, development, and behavior of organisms may become evident only when some means of statistical analysis is available. For this reason, the skills gained from the study of the SCIS unit *Variation and Measurement* will be extensively applied in the biological studies. For example, Fig. 1 illustrates the variability observed in the number of peas contained in a population of pea pods. Children analyzing such a histogram can note the range involved, the most frequent number observed, the clustering about the mode and can use that information to make predictions. "If we reach into the bag and pull out another pea pod, what is the most likely number of peas (or range) we would expect to find?" Ideas of correla-

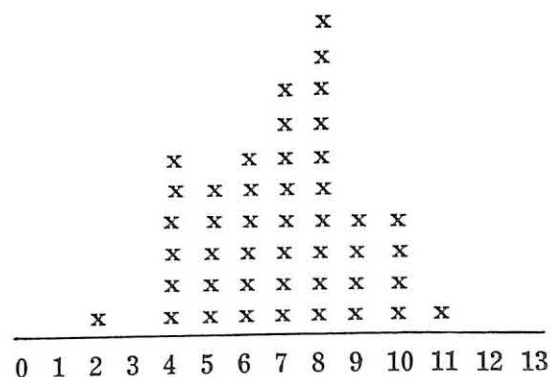


Fig. 1. Histogram of the number of peas in 45 pea pods.

tion can also be introduced. Is there, for example, a relationship between the length of the pea pod and the number of peas contained? Finally, the effect of one's criterion of measurement becomes evident. What do we consider to be a pea? Much the same thing is being accomplished by using scallop shells and variability in size, coloration, pattern, number of ribs, presence or absence of encrusting organisms, hinge structure, and placement of the muscle scar.

Systems of objects and interactions between objects within systems are emphasized in SCIS units. Systems of particular interest to biologists are organism-and-environment systems. There are a number of ways in which such systems might be studied and considerable trial work has been done with each. Just what form the ultimate units will be in is hard to say at this time. One could study the relationships between organisms and physical aspects of the environment, such as light, temperature, substratum, and mechanical or chemical stimulation. The relationships between an organism and others of the same species (i.e., those with similar characteristics) could also be investigated—intraspecific systems. Finally one could study interspecific systems. These studies could range from predator-prey relationships to parasitism.

An example of how children can become involved in such studies is afforded by the classroom study of a population of the American chameleon (*Anolis carolinensis*) housed in an aquarium. This form is already familiar to those utilizing the BSCS Laboratory Block on "Animal Behavior." Both light and temperature have an effect upon skin color, and children can determine whether color or type of background does also. A population of *Anolis* will quickly exhibit intraspecific interactions. The male display is easily studied by children and male-male, male-female, adult-young, dominant-subordinate interactions can be observed. Finally, the number and size of mealworms (*Tenebrio molitor*) eaten from the food container can be observed, perhaps in relation to such environmental conditions as temperature. In all of these studies, the children gradually become aware of the differences between observations and interpretations. The totality

of all these various interactions—ecology—also becomes increasingly evident.

When children have a good notion of what organisms do, they are ready to focus on the part(s) involved in the behavior. This may be a study of the sensory apparatus of the organism through which it acquires its information about the environment or the motor apparatus that allows it to engage in various activities. Whatever avenue it might take, this study of functional morphology can lead into the study of adaptation and might be approached comparatively by the study of (a) different groups of organisms to the same habitat, and (b) the same group of organisms to different habitats.

Another means of studying adaptation is through the presentation of a "choice" to the organism, a gradient differing in some dimension such as food size, temperature, type of substratum, color, moisture, etc. Populations of organisms may then exhibit a preference for a certain part of the continuum.

Because it focuses upon particular parts of organisms, the study of functional morphology is one way of getting at the internal factors affecting the growth, development, and behavior of organisms. The direct study of internal processes is, of course, very much more difficult for young children than are the studies thus far described. Here too, inference becomes necessary. That is, one can observe the use of certain parts of the organism for securing food, water, or air and sometime later observe eliminative behavior (defecation, urination, and expiration). One may then infer what went on inside the organism. Or, one can observe the use of some sensory apparatus to obtain information from the environment, such as a heat source, that leads to escape behavior. One may then infer what goes on in the organism to transmit the signal from the sense organ to the motor system. Actually, the study of internal factors probably becomes meaningful only when children have been engaged in extensive studies over a period of several years of how organisms grow, develop, and behave. The study of microorganisms may be another way to approach this area.

Implicit in all the activities thus far is the observation of change with time. Change it-

self has been taken as evidence of interaction. The interaction thus far discussed, however, has been more or less tied to particular stimuli and particular responses. Some types of interactions occur not so much in response to particular environmental conditions but to whole classes of conditions. Thus, growth and development occur only when there are such things as food, water, gas exchange, and an acceptable temperature range. Children have an opportunity to study growth and development when it is relatively direct, as in the case of humans, or when it involves several metamorphoses, as in mealworms. One may note that particular behaviors occur only at certain times during the growth and development of organisms; structures and functions may be different at different times in the life cycle of the organism.

Another type of change with time is learning. In fact, one of the major characteristics of most animals is their ability to learn, to change in individual behavior as the result of experience. The study of learning, from habituation, through conditioning, to operant behavior, would seem to be an important aspect of the life science sequence.

Evolution is, of course, another type of change with time. One way to approach the study of evolution might be through the study of adaptations in relation to a changing environment. One might observe that most individuals are capable of acclimating to the changing environment or that only a few individuals survive and reproduce. Perhaps there is an analogous situation here to that of the behavior-physiology problem. That is, the fact of change with time can be observed because it involves whole organisms. The genetic aspects involved in the transmission of characteristics and potentials are non-observables.

Obviously, the complete study of organisms within the confines of the classroom is extremely artificial. Therefore, the extent to which the outdoor environment (the school ground, immediate neighborhood, city park, etc.) can be utilized, even altered, for study purposes is of great interest to the Study. Actually, the form of behavior does not ordinarily change in captivity; that is, if the animal will perform the behavior at all, it, will do so normally for the species. However, the frequencies of particular behaviors may

be greatly affected by confinement. Also, because some biological phenomena do not lend themselves to direct study by children, the SCIS is interested in the possibilities of 8mm single-concept film loops.

The choice of organisms for study by children must be made very carefully in terms of their "biological importance," availability, and ease of maintenance. Obviously, there are limits to which the elementary school can be turned into a zoological and botanical garden. Too, techniques of observation and experimentation appropriate for children must be developed. Some of the animals currently being used in exploratory work are fish (guppies, goldfish, catfish), crustaceans (salt-water crabs, crayfish), birds (zebra finches, parakeets, canaries), lizards (anoles, skinks), stored grain insects (mealworms, flour beetles), mammals (albino mice, albino rats) and a variety of marine organisms. Plants are being studied in terms of their complete life cycles, interactions with the environment, and their fruit and flower development. Throughout, the organisms are studied in as natural an ecosystem as is possible.

Elementary Science Study

The ESS, one of several groups of Educational Services Incorporated, has made available through its Sampler several biologically oriented units, "Behavior of Mealworms," "Small Things," and "Growing Seeds." Numerous other units with heavy biological emphasis are being produced ("Microgardening," "Bones," "Frog Eggs and Tadpoles," "Butterflies," "Pond Water," "Peas and Particles," "Marine Life," "Mosquitoes," "Yeast," "Growing and Changing," and "Biological Environments").

The orientation of many of these investigations has been recently stated in the article "Messing About in Science"¹ by Dr. David Hawkins, former Director of ESS. Science instruction is postulated as having three phases, termed O, Δ , and $\square$ so as not to imply a mechanical order. O phase is the "Messing About" phase in which children are given *things* and *time* and allowed to explore them in a free and unguided manner.

¹David Hawkins, "Messing About in Science," *Science and Children*, 2(5): 5-9, 1965.

Although with time "Messing About" is mixed with other phases of work, "it becomes a way of working that is no longer childish, though it remains always childlike, the kind of self-disciplined probing and exploring that is the essence of creativity."

Having children mess about with natural phenomena increases the variance that one typically finds in a group of children. Having allowed children to evolve their own learning along paths of their choosing, the teacher is obliged to maintain that individuality. Hence, the Δ phase, the "Multiply Programmed" phase, in which abundant "things" (equipment, books, films, pictures, etc.) are provided to foster further explorations. The $\square$ phase includes discussion, lecturing, arguing, theorizing, etc. about those things that typically don't occur to children during the O or Δ phases of exploring the phenomenon. Science teaching in the past has been $\square$ too much of the time, often when no O has been allowed.

A brief description of the unit "Behavior of Mealworms" may serve to illustrate how the above is accomplished. The pupils begin their study of mealworms, an unfamiliar ani-

mal to most, by determining how it responds to conditions which they create.

"I dropped vinegar on his tail and he didn't like it."

"They ride on each other's backs."

"They can't walk well on smooth surfaces."

"I held my mealworm on a string out the window."

"I shined a flashlight on him and he crawled away."

A multitude of questions arise from these undirected observations and primitive experiments. How can a mealworm be made to back up? In what manner do mealworms "explore a box?" How do mealworms sense the presence of walls? How do they find a pile of bran? How do mealworms know they are under the bran pile? Table 1 gives children's data for the first question. The way mealworms find a pile of bran in a box is illustrated in Fig. 2.

According to the authors, the process of investigation is the most important thing that children learn from the unit; what they find out about mealworms is only incidental.

American Association for the Advancement of Science

The AAAS program has been called the process approach. The purpose is to develop children's skills in the processes of science (classifying, communicating, measuring, using numbers, observing, controlling variables, defining operationally, formulating hypotheses and models, interpreting data, predicting, using space/time relations, etc.), show how the processes are used, and allow for experience in using such processes. Stressed throughout all activities is the statement and appraisal of objectives in behavioral terms.

With young children the emphasis is upon such items as how the observer utilizes his senses to become aware of the environment, classification of objects such as leaves and organisms in an aquarium by their properties, describing the shapes of animals in terms of two- and three-dimensional shapes, observing the color and color changes in plants, experimenting with materials that will and will not support mold growth, and observing animal motion and populations of bacteria. Upper grade children become involved with

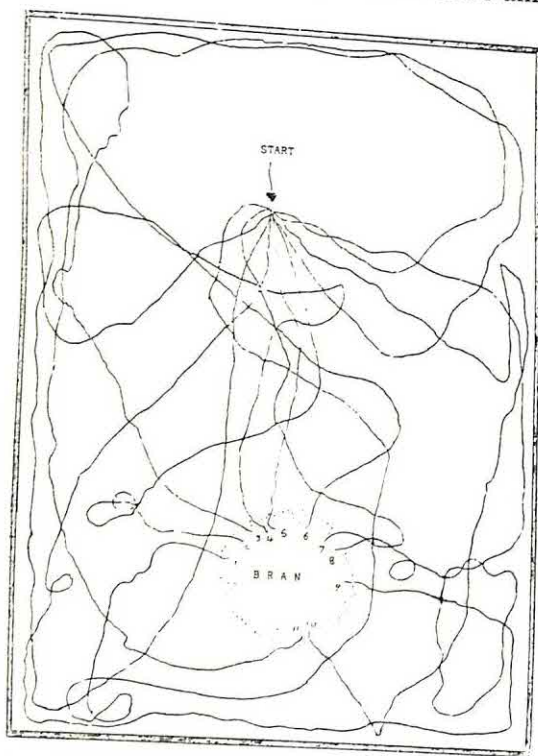


Fig. 2. Paths of mealworms in a box with a pile of bran.

such items as the operational definitions of the organs of plants, the study of learning, forgetting and relearning, human reaction time, the CO₂ expiration of organisms, semi-permeable membranes, and the growth of a simple population.

The exercise *Controlling Variables I* entitled, "Growth of Mold on Bread," will be briefly described in order to illustrate the approach. Objectives are stated in behavioral terms. Following the exercise the child should be able to: (1) identify factors in an environment which may affect an organism's growth and development, (2) state questions that are concerned with the effect of a factor of the environment on the growth and reproduction of an organism that grows on medium, and (3) identify variables to be controlled in an experiment on such an organism. The problem is originated when the teacher brings in four containers for the children to observe and then requests that they ask no more than ten questions that can be answered by a yes or a no. The containers include: (1) bread with a large amount of mold, (2) bread with only a little mold, (3) bread with no observable mold, and (4) an empty container.

Activity begins with a discussion of the word *environment* and the identification of the environmental factors for the mold. With the equipment available, the children are allowed to select a question of interest, such as the interaction of mold growth and temperature. The generalizing experience consists of considering the question: What are the combined environmental conditions for largest mold growth?

The appraisal for this lesson consists of showing the children two oranges, one with

mold and one without. The children are asked to: (1) list the variables in the environment of the oranges, (2) formulate two questions which they might ask concerning the change from no mold to the moldy state which might be answered by experiment, and (3) to state whether the same experimental plan could be used to answer both questions. The plans suggested are to include variables to be held constant and those to be manipulated.

Elementary School Science Project

The ESSP, organized in 1959 to make it possible for scientists at the University of California to contribute to the science program of the elementary school, has been developing a number of units in the realm of biology. Although the units are designed to demonstrate scientific method, the materials are not organized by the process employed but, rather, by the structure of the subject matter treated. Briefly described below are some of the units under development.

Human Physiology. A sequence of units with such titles as "How I Began" (a comparative study of the development of human and chick embryos) and "How I Move" (a study of the skeleto-muscular system) are available or being prepared.

Animal Coloration. A sequence of four units dealing with the coloration of animals: (1) the study of color and pattern variations in animals within particular species, emphasizing field observation, (2 and 3) studies of the function of animal coloration in concealment and advertisement, respectively, and (4) the study of the role of natural selection in determining the coloration of animals.

Population Dynamics. A unit making use of fruit flies to study the way in which animal populations increase or decrease in various environments.

Animal Behavior. Activities on the behavior of bees.

The Outdoor Laboratory. The aim of the unit is to devise a variety of outdoor biological observations and experiments as suggestions of how teachers may make use of natural areas accessible to their classes.

Botany. Two units on plant morphology have been written for the second grade. One

Table 1. The best way to make a mealworm back up.

What Was Done	Times Times	Times Backward	Rank from Best to Worst
Hot nail	330	247	1
Flashlight	334	198	3
Blocking with hand	242	131	4
Touching antennae with pin head	268	212	2
Mealworm at edge of paper	223	19	5

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deals with root, stem, and leaf; the other with flower, fruit, and seed.

Paleontology. A unit composed of experiments and stories dealing with fossil discoveries and their role in revealing the history of life is being tried at the upper elementary level.

Appendix

1. Science Curriculum Improvement Study (SCIS), Department of Physics, University of California, Berkeley, California 94720.
2. Elementary Science Study (ESS), Educational

Services Incorporated, 108 Water Street, Wattertown, Massachusetts 02172.

3. American Association for the Advancement of Science (AAAS), Commission on Science Education, 1515 Massachusetts Avenue, N. W., Washington, D. C. 20005.
4. Minnesota School Mathematics and Science Teaching Project (MINNEMAST), University of Minnesota, Minneapolis, Minnesota 55455.
5. Elementary School Science Project (ESSP), University of California, 2232 Piedmont Avenue, Berkeley, California 94720.
6. School Science Curriculum Project (SSCP), University of Illinois, 805 West Pennsylvania Avenue, Urbana, Illinois 61801.

New Developments in Elementary School Biology

J.D. Cunningham

(Résumé)

L'enseignement de la Biologie dans les écoles primaires n'est encore qu'à ses débuts. Il s'agit de familiariser l'enfant avec la notion générale de Science. Diverses expériences sont en cours :

1) SCIS (Science Curriculum Improvement Study)

L'enfant est mis en présence de la diversité, du dynamisme et de la complexité des systèmes vivants par l'observation directe des organismes. Le rôle des diverses interactions doit l'amener à l'étude de la croissance, du développement et du comportement vivant.

2) ESS (Elementary Science Study)

L'étude de la Biologie s'effectue en trois périodes :

O : les enfants observent librement les organismes vivants qu'ils ont eux-mêmes récoltés ;

Δ : des documents variés viennent à l'appui de leurs observations ;

□ : des discussions permettant l'élaboration de théories, amènent ensuite les enfants à poser de nombreuses questions.

3) AAAS (American Association for the Advancement of Science)

Le but est de développer l'ingéniosité de l'enfant sur le plan scientifique, de montrer comment un certain nombre de procédés (classification, observation, hypothèses et modèles, relation espace/temps ...) sont couramment utilisés et enfin de permettre la réalisation d'expérience à l'aide de tels procédés.

4) ESSP (Elementary School Science Project)

Le matériel n'est pas organisé en fonction du procédé employé, mais plutôt en fonction du sujet traité.

Nuevos adelantos de la enseñanza de la biología en la escuela elemental

J.D. Cunningham

(Resumen)

La enseñanza de la biología en la escuela primaria esta todavía en sus comienzos. Se trata de familiarizar al niño con la noción general de ciencia. Se están haciendo varios estudios experimentales :

1) SCIS (Science Curriculum Improvement Study)

Se pone al niño en presencia de la diversidad, del dinamismo y de la complejidad de los sistemas vivientes mediante la observación directa de los organismos. El juego de las diversas interacciones debe llevarle al estudio del crecimiento, del desarrollo y del comportamiento del ser vivo.

2) ESS (Elementary Science Study)

El estudio de la biología se divide en tres periodos :

○: los niños observan libremente los seres vivos que ellos mismos han colectado ;

△: esas observaciones se refuerzan con documentos variados ;

□: mediante charlas que permiten formular teorías, se induce después a los niños a hacer numerosas preguntas.

3) AAAS (American Association for the Advancement of Science)

Se procura desarrollar el ingenio del niño en el plano científico, mostrarle cómo se utiliza corrientemente un cierto número de procedimientos (clasificación, observación, hipótesis y modelos, relación espacio-tiempo, etc.) y facilitar la ejecución de experimentos con ayuda de esos procedimientos.

4) ESSP (Elementary School Science Project)

El material no se organiza en función del procedimiento empleado sino más bien en función del tema tratado.

THE PART PLAYED BY SCIENTISTS IN MODERNIZING
THE TEACHING OF BIOLOGY IN SECONDARY
SCHOOLS IN CZECHOSLOVAKIA

by

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A comparison between the present teaching of biological sciences in primary and secondary schools in Czechoslovakia, and the present state of development of biological science, both basic and complex, special and general and theoretical and practical, demonstrates the need for great changes in both the content of and methods used in giving biological instruction. The school curriculum must always be in harmony with contemporary scientific knowledge. The exponential rate of development of the sciences, and particularly all branches of natural science, in the past twenty years has resulted in a lag between scientific and technical advance and its incorporation into the school curriculum, despite frequent alterations being made in an attempt to keep pace. The rapid and effective means of informing the public about scientific and technical development via the mass media, notably the press, radio and television, have contributed in no small degree to the fact that any lag in adapting the teaching of science to the actual state of knowledge becomes subject to public criticism. Modernization has become the slogan of the day. We have become accustomed to speaking of the modernization of the content and methods of education, just as we speak of a modern furnished apartment, modern transport system, modernization of the administration, etc. The modernization of a teaching system, however, is a complex and exacting task. To make it a real success, a real advance, the close cooperation of competent experts in science, theoretical educationalists and teachers, and, last but not least, the public, is absolutely essential.

Since 1964, a large number of discussions on the whole problem of and requirements for improving instruction in biology in primary schools and particularly in secondary schools, have been held in the Philosophical Circle of the biological institutes of the Czechoslovak Academy of Sciences. Leading scientists and research workers in the field of biology, university professors, representatives of the Education Research Institute, and officials of the Ministry of Education took part in the meetings.

The discussions held so far have led to the following conclusions :

1) The need is generally felt for a new delineation of the aims and content of biological instruction in primary and secondary schools, in view of the present state and continuous development of the biological sciences

and the perspective standard of scientific knowledge demanded of young people. This includes also evening and extra-mural courses for people who are employed. It includes, in particular, an overall knowledge of the "principles of biological science", of the biological problems most relevant from the point of view of the scientific-technical revolution and of the further development of Mankind, and problems of hygiene, nutrition, and concern for the environment in which we live. Another aim is the utilization of biological studies as an important means of training thought processes and developing the habit of acquiring new knowledge of a similar type, especially through the study of mathematical and other abstract theoretical branches (and, in a certain sense, as a counterbalance to it).

2) Having in mind the target and tasks of comprehensive biological education, to select and classify biological subject matter into three mutually dependent grades in relation to the specific needs of the nine-year-primary schools and the three-year-secondary schools as follows :

Grade I : (elementary and propedeutic level) represent the curriculum for the first to fifth year of the primary schools (elementary schools) where children are introduced to the most common objects and processes of living and non-living nature through sensory perception and where they acquire some basic physical, chemical and biological conceptions, the knowledge of which is necessary for the systematic study of natural science (biology, mineralogy and geology), physics and chemistry, in the sixth to ninth years of the nine-year-primary schools.

Grade II : (intermediate, mostly descriptive and classificatory) providing an overall system of theoretical and practical knowledge and proficiency in botany, zoology and the biology of Man in the field of biology, with due regard to elementary biological concepts of the laws governing the relation between organisms and their environment, of heredity and of the evolution of organisms.

The aim of these two grades of biological instruction in the nine-year-primary schools is to give school children the essential basis, reliable from the scientific point of view, for both practical life and further study (or self-education) and the ability to use this knowledge as a means and instrument for dealing with problems in their future occupation and their daily life. A system of fostering interest in biology, which is voluntary and out of obligatory school hours, is to be developed in the form of biological circles, seminars, etc., including practical classes and excursions into the country, to museums and enterprises engaged in biological production (agricultural cooperatives, forestry, fisheries, apiculture, etc.), as a source of additional education for children intending to continue at secondary schools (tenth to twelfth year) or at specialized schools where biology constitute part of the specialized curriculum.

Grade III : (higher, secondary school level) is mainly of an experimental and analytical character (physiology, ecology, genetics) especially in the first two years. It is concluded by a final, synthetic (integrating) general course in biology in the last year, with emphasis placed on the scientific conception of the universe. This is mainly com-

posed of a study of biochemical and biophysical methods of observing life, the essential principles of genetics and evolution, and a survey of the history of biology.

3) To work out the main principles of teaching biology on the basis of a critical revaluation of the existing curriculum, methods and organization of biological instruction, with consideration for experience in the teaching of biology from other countries. The following steps are viewed as the most important :

- a) To overcome and do away with the excessive factology (encyclopedics) and senseless memorizing of schematic reviews of the subject.
- b) To develop to the full the pupils natural interest in biology by utilizing the present knowledge of the psychology of learning and of the child's personality.
- c) To elaborate and correctly use methods involving independent study by the pupils from the textbook (including independent preparation at home).
- d) To utilize the most important examples from the history of biological discoveries and their practical application, for educational purposes and methodologically.
- e) To work out the consistent coordination and continuity of biological subject matter with that of other branches of science, primarily chemistry and physics.

4) To elaborate proposals for a new program of studies and new textbooks of biology based on the relevant scientific foundations and on a mutual agreement in principle among research workers in biological sciences, professors, specialists in education and teachers. The main principles for this appear to be the following :

- a) The contents of the textbooks should not be limited to the essentially necessary subject matter (i.e. the basic curriculum), but should enlarge upon it in such a way that the textbook would not merely fix the newly acquired knowledge, but should also constitute an accessible and attractive source of additional information to promote the pupil's interest in the subject and favour his independent thinking. The textbooks should thus include, for example, the history of the great discoveries, the etymology of terms, stimuli for the deeper consideration of problems and for additional voluntary study, suggestions for experiments, observations, and the collecting of scientific material. Each chapter should be concluded by questions for repetition, for inducing thought about the main principles, making reviews, etc.
- b) The respecting of the basic didactic principles, such as consistency, system, correlation and the utilization of experience with programmed texts.

5) To consolidate and improve the training and systematic postgraduate education of biology teachers according to the following principles :

- a) To make it possible for every teacher to undertake work for one to two months in research institutes (on a voluntary basis, with possible concessions in their teaching duties) ;
- b) To publish as soon as possible the necessary modern manuals for teachers, or if necessary, to translate them from foreign literature ;
- c) To educate teachers for independent scientific work (regional research, ecology, ethnography, etc.) and for independent work in didactic biology and to stimulate their interest in both by adequate measures ;
- d) To extend and improve the systematic postgraduate training of teachers .

6) To improve the preparation of pupils for the university and make it more systematic by voluntary non-compulsory instruction (biological circles, excursions, stimulating independent experimentation, collection of natural objects without breaking the principles of nature conservancy), etc. To keep libraries supplied with popular literature on biology, to organize regular competitions (olympiades) in biological knowledge and activities (observations, experiments) for pupils within certain age limits, to promote the interests of children in this field in the children's organizations (Pioneer Houses) and to establish young groups within scientific societies, etc.

7) To improve and coordinate systematic research on biological teaching in schools and to favour experimental research. To promote the regular study and utilization of experiences with teaching biology abroad. To stimulate the interest of teachers in using modern psychological and sociological knowledge.

8) To create a permanent forum in which interested research workers, specialists in the didactics of biology, officials of the educational authorities and teachers could meet regularly to discuss topical problems and experience in teaching biology and to stimulate concrete work on measures for improving instruction in biology as has already been done in this country with chemistry, physics and mathematics, etc. It could start in the form of a commission of the Psychological-Pedagogical Collegium (advisory board) of the Czechoslovak Academy of Sciences that would then, in the next phase, prepare for the founding of a scientific society for this purposes .

Le rôle des savants dans la modernisation de l'enseignement de la biologie dans les écoles secondaires en Tchécoslovaquie

V.J.A. Novak et A. Vodicka

(Résumé)

Les conclusions suivantes sont le résultat des nombreuses discussions sur la modernisation de l'enseignement de la biologie dans les écoles secondaires, discussions auxquelles prirent part les chercheurs des différentes branches de la biologie, les professeurs d'universités ainsi que les pédagogues-spécialistes.

- 1) Il faut réviser le but et la matière de l'enseignement de la biologie par rapport aux exigences actuelles et futures, en ce qui concerne le caractère et l'étendue des connaissances de la biologie, envers ceux qui termineront l'école secondaire.
- 2) Il faut orienter les exigences nouvellement établies de l'enseignement sur les trois degrés de l'enseignement obligatoire (dans les écoles primaires et secondaires) en prenant en considération leurs besoins et possibilités spécifiques.
- 3) Il est désirable d'élaborer les plus importants principes de l'enseignement suivants :
 - a) éliminer le caractère encyclopédique de l'enseignement,
 - b) stimuler systématiquement l'intérêt actif pour la biologie auprès des élèves,
 - c) développer et exploiter la méthode de l'étude préliminaire des élèves d'après les manuels spéciaux,
 - d) assurer la pleine coordination de l'enseignement de la biologie avec les autres sciences naturelles (notamment la chimie et la physique).
- 4) Elaborer des nouveaux programmes de l'enseignement et des nouveaux manuels de biologie sur la base de l'état actuel de la science en respectant les dernières connaissances scientifiques sur l'éducation et la psychologie.
- 5) Consolider et élargir l'éducation postscolaire des enseignants qui devrait comprendre un stage de 1 à 2 mois dans un laboratoire de recherches.
- 6) Elaborer un système de cercles d'études volontaires d'étudiants, surtout de ceux, qui ont l'intention de continuer ces études à l'université.

- 7) Maintenir des contacts étroits avec l'enseignement de la biologie dans les autres Etats et de gagner ainsi un aperçu des nouvelles méthodes d'enseignement à l'étranger.
- 8) Etablir une plate-forme (commission ou société) sur laquelle pourraient se rencontrer régulièrement les biologistes avec les spécialistes de l'éducation et ceux qui enseignent la biologie et d'assurer ainsi une amélioration constante de l'enseignement de la biologie comme il en est pour l'enseignement des mathématiques, de la physique et de la chimie en Tchécoslovaquie.

La función de los hombres de ciencia en la modernización de la enseñanza de la biología en las escuelas secundarias de Checoslovaquia

V.J.A. Novak y A. Vodicka
(Resumen)

Las siguientes conclusiones son el resultado de numerosos debates sobre la modernización de la enseñanza de la biología en las escuelas secundarias, debates en los que han participado investigadores de diferentes ramas de la biología, profesores universitarios y pedagogos especializados.

- 1) Hay que revisar la finalidad y el contenido de la enseñanza de la biología en función de las exigencias actuales y futuras, en lo que se refiere al carácter y a la extensión de los conocimientos biológicos, en interés de los alumnos que terminarán la escuela secundaria.
- 2) Hay que orientar las nuevas exigencias de la enseñanza en los tres grados de la enseñanza obligatoria (en las escuelas primarias y secundarias) tomando en consideración sus necesidades y posibilidades específicas.
- 3) Es conveniente aplicar los siguientes principios fundamentales de la enseñanza :
 - a) eliminar el carácter enciclopédico de la enseñanza,
 - b) estimular sistemáticamente el interés activo de los alumnos por la biología,
 - c) desarrollar y explotar el método del estudio preliminar realizado por los alumnos en manuales especiales,
 - d) procurar la plena coordinación de la enseñanza de la biología con la de las otras ciencias naturales (en particular, la química y la física).
- 4) Preparar nuevos programas de enseñanza y nuevos manuales de biología a base del estado actual de la ciencia y respetando los últimos conocimientos científicos sobre la educación y la psicología.

- 5) Consolidar y ampliar la formación postescolar de los profesores, que deberá comprender un periodo de 1 a 2 meses en un laboratorio de investigación.
- 6) Organizar un sistema de círculos de estudios voluntarios de los alumnos, en particular de los que tiene la intención de continuar esos estudios en la universidad.
- 7) Mantener estrechos contactos con la enseñanza de la biología en los otros países para estar al corriente de los nuevos métodos de enseñanza aplicados en el extranjero.
- 8) Establecer una tribuna (comisión o sociedad) en la que puedan reunirse regularmente los biólogos con los especialistas de la educación y los profesores de biología para conseguir así un mejoramiento constante de la enseñanza de la biología como se hace con las matemáticas, la física y la química en Checoslovaquia.

Biology in Indian High Schools

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UNLIKE their counterparts in America and European countries, biologists in India have a double task before them. First, they have to modernize the existing curricula and methods of instruction in biology, and thus strive to improve the public image of biology. Secondly, they have to convince the educational authorities of the importance and necessity of making biology a compulsory part of general education so that the citizens may serve the needs of a democratic country more intelligently. This problem is a part of another larger task before them, namely, removing the deficiencies of the existing system of biology instruction and bringing it in line with modern trends in science learning. While in other countries the status of school biology has been steadily improving with the all round academic improvement, the biology curricula in Indian schools and colleges have remained almost unchanged ever since they were introduced—in some places as far back as 150 years ago. An attempt is made in this survey paper to analyze the existing problems, and the steps being currently taken for improving the teaching of biology in Indian schools. Some of our problems are common to those faced by other countries; certain others are peculiar to India, and perhaps to a few other developing countries of Asia.

PRESENT STATUS OF SCHOOL BIOLOGY

In India there are two kinds of school courses—High School (2-year course after 8 years in pre-secondary or Middle school) and Higher Secondary course (3-year course after 8 years in Middle school). In high schools there is no biology curriculum as such; it forms only a part of the General Science curriculum. The student learns little beyond gaining some familiarity with a few plants and animals, and an elementary idea of digestion, respiration and photosynthesis. In most high schools there is either no laboratory work at all, or it is limited to the description of just a few plants and animals with the help of specimens, models, charts and slides.

BIOLOGY CURRICULUM IN HIGHER SECONDARY SCHOOLS

Much of the following discussion is concerned with biology in the higher secondary course (3-year course after the middle stage). It is taken as an elective subject by science students. A look at the old syllabus shows that the main emphasis is on structure, definitions and explanations. There is a traditional division of the course into Botany and Zoology, both of which are treated as a closed and completed

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story where there is nothing to do except to remember the shapes of leaves, the forms of roots and stems, and the skeletal and other systems of frog as well as other animals. In this morphology-anatomy dominated curriculum, physiology, ecology, genetics, microbiology and the interrelations of plants and animals receive negligible attention. The curriculum presents an endless series of technical terms and lengthy descriptions which do not mean a thing to the beginner, and yet he must memorize them. In his struggle with these terms he often fails to appreciate the real odour of the subject. Another surprising aspect is that the study of human biology is completely omitted. Thus, the student remains completely ignorant of the functioning of his own body though he becomes familiar with the smallest bone of a frog and the details about the life cycle of a honey bee.

On the whole, the syllabus is primitive in content, too mechanical in approach, and too dull and boring to pursue. Perhaps the only object served by this scheme is that the students who manage to memorize a certain mass of facts and get through the examination become eligible for entrance into a university or a medical college. The syllabus together with the approach followed in its presentation, fails to give the students an insight into the fascinating world of life of which they themselves form such an important part.

This curriculum has been, in part at least, responsible for adversely affecting the status of biology and in making

the subject the least popular of all sciences.

The reasons for these defects in curriculum can be traced to the origin of higher secondary courses. Surprisingly enough biology was not taught in Indian schools till as late as 1940; it used to be taught only in the Intermediate colleges, representing the first stage of a degree course. With the adoption of secondary system of education—in most states after 1945—elective and compulsory courses in biology were introduced. The biology courses at the Intermediate college level were rather hurriedly and, shall we say thoughtlessly, condensed to about 80 per cent, and prescribed for the higher secondary classes. It may be noted that the syllabuses of the Intermediate colleges which formed the genitor of the school syllabus were themselves quite outmoded—they were introduced at the turn of the present century. Thus, all the dead weight of the primitive Intermediate syllabus steeped into the school syllabus.

After the inception of the National Council of Educational Research and Training, Government of India, a new syllabus was drafted in 1964. Although there has been a lot of resistance to adopting even this not-too-modern curriculum, it is encouraging to note that several states have finally come forward to give it a trial. The principles followed in drawing up this syllabus are discussed later in this paper.

Reading Material Used by Students

The course content being largely similar to the Intermediate college

curriculum, the books used in secondary schools are generally the same as those used in Intermediate colleges. The paucity of suitable textbooks for schools is reflected in the fact that many boards of secondary education do not prescribe a textbook; they only recommend certain college books. The Central Board of Secondary Education in Delhi, for instance, recommends the following books:

1. *An Elementary Textbook of Zoology* by T. J. Parker and W. N. Parker; Macmillan and Co., Ltd., London, 1952.
2. *The Frog* by A. M. Marshal; Macmillan and Co., Ltd., London, 1930.
3. *Skeleton of Indian Frog* by M. L. Bhatia; Maxwell Publication, Lucknow, 1952.
4. *A Class Book of Botany* by A. C. Datta; Oxford University Press, Bombay, 1965.

Most of these 'recommended books' are actually college level books of a rather specialized type, and are written by foreign authors exclusively or in collaboration with an Indian author. In addition to these there are many books by college teachers of botany and zoology. Most of the latter books are devoted exclusively to lengthy descriptions studded with hundreds of technical terms and their definitions. A large fund of biological information acquired during the present century finds no mention. The biological concepts and principles, and their application in daily life become obscure in the maze of descriptions and terminology. The books achieve little in developing

the scientific outlook and experimental attitude of mind. The diagrams and printing leave much room for improvement. Since both curricula and existing textbooks demand a lot of memorization from the student, there is a tendency for further consolidation and condensation of the matter to its barest essentials. The result is the production of certain cheap or "made-easy", matter-of-fact books. These are nothing more than compendia of definitions and brief notes on the more important subjects which the student may memorize verbatim.

Thus, the reading material available to the student neither presents the subject in a scientific way, nor gives him a glimpse of the fascinating ways of plants and animals in their natural surroundings.

Laboratory Work

There is an appalling over-simplification of laboratory work. Field work and experimentation have no place in it. The emphasis on bookish knowledge is indeed so great that the students are often not acquainted with the beautiful fauna and flora of their own locality. In most schools the students attend the laboratory twice a week for 70-80 minutes on each turn. They spend most of their time in observing and dissecting the various plants and animals included in the syllabus, in making labelled diagrams of the entire or dissected specimens, in copying figures from charts, and in looking through the microscope. They also get a chance to observe the set-up of a few experiments in plant physiology. Since the laboratory hour is of short dura-

tion, the students rarely have the opportunity of seeing any experiment to its completion. The teacher, who has to look after a class of 30-35 students, often without a laboratory assistant to help him, cannot manage to demonstrate the experimental results on a quantitative basis.

Thus, there is no scope for the student to find out anything for himself through experimentation. The student's performance is judged by the quality of diagrams in his practical record book. Many 'good' note-books contain diagrams neatly copied from books and charts.

The laboratory work prescribed by most schools runs as follows :

Botany: Description and dissection of the types included in the syllabus for written examination. Demonstration of experiments in physiology, and identification of microscopic slides of tissues included in the syllabus for written examination.

Zoology: Dissection and skeleton of frog. Identification of animals and slides (microscopic) of specimens included in the syllabus for written examination.

School Teacher

The Commission on Secondary Education in India had laid down that the students in the higher secondary schools should be taught by post-graduate (M.Sc.) trained teachers. However, the salaries of teachers are not adequate to give them the dignity and status which their work demands. Their chances for promotion are too few. Teaching profes-

sion, therefore, attracts the least promising men and women, and there is an acute shortage of really good, trained teachers. In many schools science graduates teach biology for one, two, or even all the three years (i.e. classes IX, X and XI). Heavy duty (25-35 periods of 40-45 minutes each, per week) and poor remuneration prevent the teachers from putting their heart into the work, and they are often on the look-out for non-teaching, more prosperous jobs.

Even where trained post-graduate teachers are employed, the teaching remains stereotyped and sometimes even unbalanced. The teachers are specialized in classical biology—either botany or zoology. Depending upon his specialization, he may do full justice to one branch but may accord a stepmotherly treatment to the other. Quite often they influence the future choice of subject by the students studying under him. The teacher's initiative is often curbed by the stereotyped curriculum; his teaching becomes dull and lifeless due to the pressure of the dead weight of examinations which often demand little more than a good memory.

REFORMS—ACHIEVED AND ENVISAGED

The facts enumerated here tend to show, rather dismally, that the reformatory task before the Indian biologists is not only enormous but also difficult. They have to exercise restraint and patience in uprooting the evil which is several decades old and which has taken the shape of a vicious circle composed of several limiting factors. However, the brighter and encouraging side of

the picture is that given proper guidance and facilities, the Indian student is prepared to accept the change and turns out as meritorious as his counterparts in any part of the world. The rock of finance on which excellent schemes come to grief is one of the major hurdles. But in this respect we have been lucky in getting substantial monetary help from some friendly countries particularly the USA and USSR. With this assistance the Government of India has taken, during the past five years, many bold steps with a view to bringing an all round improvement in school curricula. Some of these steps are outlined below.

Development of a New Curriculum and Textbook

The National Council of Educational Research and Training approached one of the most eminent biologists, the late Professor P. Maheshwari, to set up and guide a Biology Panel. The Panel consisted of 16 representatives—professors, teachers and research workers from several universities and research institutions. This Panel has drawn up a revised curriculum and prepared a new "Textbook of Biology for Higher Secondary Schools". The Chairman had maintained a close contact with modern developments in biology in other countries, and much as he would have liked to go hand in hand with the practices of the times, he had to restrain himself in the design of the curriculum and the textbook in view of the prevailing situation.

The members of the Panel consider-

ed several ways of approaching the subject and discussed their merits and demerits. Finally, they decided that, in view of the prevailing standards and practices of teaching in Indian schools, it would be desirable to adopt, for the time being, a modernized traditional approach. The members agreed that a wide acquaintance with a number of different kinds of organisms, their activities, habits and their tissues and organs, is essential and basic to the understanding of the general concepts of evolution, ecology, heredity, and cell physiology. This approach, in their opinion, combines not only the pedagogical advantage of proceeding from known to the unknown but also prevents students from getting lost in the intricacies of the more advanced aspects of biology.

They also decided that evolution be treated separately in two chapters, but an attempt be made to acquaint the student with this all pervasive principle during his study of the world of life. Biological phenomena common to plants and animals are to be discussed together as far as possible, but this should not be carried too far because there are several aspects of plants as well as of animals which deserve independent treatment. It was decided that technical terms be kept down to the minimum except where their use contributes to easier communication and understanding. Important biological discoveries are to be dealt with in a historical perspective to give an idea of how science progresses.

The book has been divided into seven, more or less independent sec-

tions. In the first section the student is introduced to the subject matter of science, particularly biology, and the characteristics of the living matter. A glimpse of the variety of plant and animal life prepares the student for a more detailed study of these forms in the second and third sections. The fourth section treats the main physiological processes in animals and plants in a simple way. The fifth is devoted to a comparative account of the different modes of reproduction in the plant and animal kingdom. Heredity, evolution and ecology form the sixth section of the book. The epilogue to the book covers topics like human diseases, interdependence of plants and animals, and the role of biology in human welfare.

It is encouraging to note that almost all the schools under the Central Board of Secondary Education in Delhi and in some other states have agreed to give the new curriculum and the textbook a fair trial.

It may be pointed out that the late chairman (Professor P. Maheshwari) of the Biology Panel was not dogmatic and did not consider the new syllabus the only suitable approach. He was of the opinion that several agencies or individuals should be entrusted with preparing other versions of the subject and the schools should be free to choose the text best suited to their needs.

In the meantime, the National Council has also reprinted the BSCS Biology Textbook—'An Inquiry into Life,' at a

low cost. The related books on laboratory work and Teacher's Guide have also been made available. Because of the different background these books have a limited use, and an Indian adaptation of this work would perhaps be of immense help to teachers and students.

Recently, the Directorate of Extension Programmes for Secondary Education drafted a syllabus in General Science for Classes I to VIII with the help of specialists and science teachers drawn from various Indian States. This syllabus is now being re-examined and revised. The introduction of this syllabus will improve the primary stage of education and will make the introduction of reforms at the higher secondary stage much easier.

Laboratories and Equipment

The Government of India has been giving assistance to State Governments for the introduction of elective science courses in higher secondary schools. In addition, assistance was also given during the first two 5-year Plans for the strengthening of science through construction of Laboratories and purchase of apparatus.

Recently, a panel set up by the Committee on Plan Projects of the Planning Commission drew up laboratory designs and lists of equipment for higher secondary schools.

In-Service Programmes

The Directorate of Extension Programmes for Secondary Education has been organising a large number of in-

service programmes for the benefit of secondary school science teachers. These programmes have dealt with dynamic methods of teaching science, preparation and use of teaching aids, co-curricular activities in science, lesson plans, evaluation, etc. Several Extension Centres also organize workshops to acquaint teachers with the implications of the revised syllabus introduced in their States. These in-service programmes have brought a keener awareness among science teachers of the new concepts and techniques of science teaching.

Exchange of Science Teachers

In 1958, forty teachers in science, selected from training colleges and secondary schools in the different States, were deputed to study modern methods of science teaching in the UK, USA, and Canada, under the Government of India scheme for the strengthening of science teaching in the country.

On their return to India, the Directorate organised a 5-day seminar in July 1959 to pool the experiences which they gained abroad and to draw up a comprehensive programme of science education at all levels. The suggestions made by the group were considered by the All-India Council for Secondary Education, and were also incorporated subsequently in the programme of science education drawn up for the third Five Year Plan. This programme is being followed more extensively.

Television Lessons

A programme of television lessons on physics, chemistry and biology for the

higher secondary classes has been introduced in Delhi since 1961-62. Each lesson lasts for 20 minutes, and is preceded by an introduction by the subject teacher for 10 minutes and followed by a review for another 10 minutes. The scheme was started for Class IX and has now been extended to Class X.

Science Clubs

A programme of establishing Science Club activities in secondary schools was initiated during 1967-68 by the former All-India Council for Secondary Education, and was continued by the Directorate of Extension Programmes for Secondary Education and the Department of Science Education of the NCERT. At present it covers well over 1,114 schools. A non-recurring grant of Rs 1,200 for the purchase of tools and equipment is given to each school covered by the programme. In addition to these, eight basic schools have established Science Clubs with a non-recurring grant of Rs 3,001 for each school.

The aim of the programme is to provide opportunities for experimentation in science with a view to stimulating the interest of young pupils studying science, besides encouraging the pursuit of science as a hobby. The facilities provided by the clubs are utilized by the members for individual and group projects, and the science teachers try to correlate the club activities with class-room teaching wherever possible.

In addition to School Science Clubs,

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60 Central Science Clubs to serve as energising centres have been established in selected training colleges where Extension Services Centres are located. A non-recurring grant of Rs 2,000 is given to each Central Science Club towards the purchase of equipment.

	1962-63	1963-64	1964-65	1965-66
District Science Fairs	—	—	283	264
State Science Fairs	—	2	2	5
Regional Science Fairs	56	80	77	79

Science Fairs

Early in its programme of improvement of science teaching, the NCERT considered it necessary to introduce a programme of Science Fairs. This was to support the programme of science clubs and to encourage pupils, teachers and the public to take a deeper interest in scientific advances and scientific methods. The All-India Council for Secondary Education, at its second meeting held early in 1960, recommended that a programme of All-India Science Fairs should be organized, preferably on the first of December each year, followed by a Science Week when various types of programmes, such as science exhibitions, lectures, film shows, symposia and similar activities could be organised. During the year 1960, Madhya Pradesh conducted a State-wide programme of Science Fairs. In 1961, the 54 Extension Services Centres were requested to organise Science Fairs with the help of their associated schools, and an amount of Rs 500 was made available to each centre for this purpose. The response was very encouraging and a large number of schools participated in this programme and conducted a variety of activities. During the subsequent four years Science Fairs were held at 3 levels as stated below:

National Science Talent Search

As part of its comprehensive programme of science education, the Government of India have formulated a programme of Science Talent Search under which promising science students of the final year in the secondary schools are selected through suitable procedures and given scholarships and certificates of merit. The main objectives of the scheme are (a) to identify boys and girls who possess a marked aptitude for science, (b) to stimulate scientific talent by creating a healthy competition for recognition of merit, (c) to encourage schools to take more active interest in the search for scientific ability, (d) to expose the talented students to the challenges in science, and (e) to build up a body of future scientists who will contribute to the scientific advancement both in the applied and pure science. The scheme will also help in bringing about improvement in the methods of teaching science in the schools.

The scheme was started in 1963 and is now running its fifth year. Every year about 350 talented students are selected for the award of scholarship on the basis of (a) An aptitude test, (b) An essay competition, (c) A project report, and (d) An interview by a com-

mittee of specialists. The students are required to pursue a course leading to a degree in basic sciences. For the first three years of study (for the B.Sc. degree) the awardees get Rs 100 p.m. as scholarship and a book allowance of Rs 100 per annum. The scholarship is continued beyond the B.Sc. stage if the awardee passes his examination in the first division and joins the M.Sc. class. After that it may be continued for another three or four years during his doctorate work in basic science. The scholar will be paid Rs 250 p.m. at this stage and Rs 350 p.m. at the Ph.D. stage. In addition, the tuition fees will be reimbursed. The Department of Science Education of the NCERT will try to place these scholars at the centres of Advanced Studies and at such Universities where well-known scientists are working. The book awards will also continue during the M.Sc. and Ph.D. stages at Rs. 250 and Rs 500 per annum.

As a follow-up programme the awardees are invited to attend a one month Summer School during the B.Sc. and M.Sc. stages. At these schools the students are offered an accelerated programme of science instruction, so that they can acquire enough knowledge and motivation to pursue a career of research in science.

Summer Institutes for School Teachers

This is a programme of in-service training of school teachers for a period of 4-6 weeks, sponsored jointly by the NCERT the University Grants Commission, and the U.S. AID. These institutes are designed to inspire the school tea-

chers to continue learning in their fields so that they constantly strive to increase their understanding and competence. The teachers attending these institutes also learn new ways of teaching science, especially such methods as would enable the students to learn science by discovering truth rather than merely studying descriptive science. The programme had a small beginning in 1963 when only four institutes, one in each major science subject, were held. The positive impact of these institutes greatly encouraged the expansion of this programme, and in 1965 there were as many as 43 institutes, of which 8 were devoted to biology. In all 761 biology teachers have been benefited by this scheme.

Participation of US National Science Foundation

The U.S. AID/India recently sought the cooperation of the U.S. National Science Foundation to implement a large scale, year-round programme of academic support to modernize curricula, laboratories and teaching aids. Accordingly, an Indo-American Conference on Scientific and Technical Education in India was held in New Delhi from May 1 to 5, 1966. It was resolved in this conference that the Government of India and NSF/AID will co-operate for the next few years in a programme of follow-up activities designed to make much more effective the summer institutes now going on in India. The follow-up activities include preparation of textbooks, teacher guides, and curriculum materials; strengthening of the libraries; and designing as well as manufacturing of

laboratory apparatus, etc. A working conference held from June 20 to 27, 1966 at Srinagar has worked out the details of this programme, and with the grant made available by the NSF, this scheme would have much impact on the improvement of science in India.

CONCLUSION

Ours is a race on many fronts. On one side we are called upon to catch up with the times—to imbibe and assimilate the recently accumulated fund of knowledge, without wasting any time. In other words, we have to pick up and reach where other countries

already are. On another front, we have to fight with the ever-increasing demands in terms of trained teachers, laboratories, text books and other teaching aids. The expansion is required on such a vast scale that most of our efforts become greatly diluted, and the results therefore appear discouragingly disproportionate. To serve our needs best, we have to do more of indigenous thinking and effort, and in this we can derive much benefit from what other countries have done and from the generous help, both in cash and in personnel, which many friendly countries are so generously offering.

ACKNOWLEDGEMENTS

We are indebted to the late Professor P. Maheshwari FRS, who pioneered a team of biologists interested in the improvement of biology curricula in Indian schools and colleges. Many of the observations made in this article emanated from our discussions with that illustrious teacher. Thanks are also due to Mr. S. Doraiswami for furnishing some up-to-date data included in this article.

APPENDIX 1

ASIAN REGIONAL CONFERENCE ON SCHOOL BIOLOGY

Manila, December 4-10, 1966

RECOMMENDATIONS

I. On the Aims of School Biology Teaching in Asia

1. Develop and instil in students the scientific attitude of inquiry and experimentation.
2. Provide sufficient understanding of the concepts of biology to enable students to become worthy citizens of the world.
3. Provide the opportunities for a practical understanding of the methods of the biologists which will give them the confidence to attempt the solution of problems which they have to face in their individual and social lives.
4. Give students the incentive to pursue the study, at the higher levels, of biology and related fields.
5. Encourage respect and feeling for living things.

To achieve the foregoing aims, the following criteria for the selection of content of secondary school biology in Asia are recommended:

1. It must inculcate the idea of science as inquiry.
2. It must consider the pertinent problems and needs of the community and emphasize the study of local *flora* and *fauna*.
3. It must be presented in a logical and coherent manner based on the following themes:
 - a. The intellectual history of biological concepts.
 - b. The change of living things through time (evolution).
 - c. Diversity of type and unity of pattern in living things.

- d. The genetic continuity of life.
 - e. Interdependence of organism and environment.
 - f. Biological roots of behaviour.
 - g. Correlation (complementarity) of structure and function.
 - h. Regulation and preservation of life in the face of change.
4. The class time allocated to the subject shall, ideally, be not less than 180 full hours.
 5. The content must correlate biology with other school subjects.
 6. Consideration should be given to the best information available regarding students' learning processes.

Considering that biology plays an all-pervading and vital role in the life of every man, it must be taught as a required subject in all secondary schools.

Sufficient laboratory facilities for biology must be made available in all secondary schools.

II. On Teaching Methods and Teacher Training

A. Teaching Methods

1. Emphasis should be on practical laboratory work and field study in order to give the pupil experience in scientific inquiry. For proper implementation, the following points are suggested:
 - a. Observations to be made should be guided by a list of questions.
 - b. In planning practical work, existing facilities should be taken into consideration and improvisation should be encouraged.

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- (1) When no laboratory facilities are available, the following may be resorted to:
 - (a) Demonstrations, in which students take part in the planning. Each step must be understood by everyone, ensuring that each demonstration becomes a cooperative activity;
 - (b) Improvising a mobile laboratory table with supplies and equipment or unit kits that can be rotated among different groups in the class; home work may be assigned.
- (2) When partial use of the laboratory is possible, the above practices should be combined with use of the laboratory.
- (3) When adequate laboratory facilities are available, these should be used to the best advantage.
- c. Laboratory experiments should be planned to fit the level of the pupils being taught.
- d. As much as possible, local biological materials should be utilized.
- e. Emphasis should be laid on quantitative measurements. Accurate and systematic methods of recording and presentation of observations should be practised.
- f. Interpretations and conclusions should be discussed in the class under the guidance of the teacher.
2. Group discussions and active participation by pupils should be encouraged to the maximum. Lecturing by the teacher should be minimized.
3. As much as possible, practical applications of biological principles should be emphasized.
4. Teaching aids such as specimens (preferably live ones), models,

charts, films, slides, filmstrips, etc. should be used to help present the lesson more interestingly and effectively.

5. Written and practical examinations should be designed to provide the teacher with relatively accurate evaluation of the effectiveness of his teaching.
6. Biological gardens and museums are useful means for effective instruction, and should be availed of.
7. Auxiliary readings to supplement the text should be encouraged.
8. Pupils should be given incentive to collect information on topics of biological interest from sources other than books and should be encouraged to present this information in the classroom.
9. In case educational television is used, there should be close coordination between the producers of the programme and the teachers using TV materials in order to bring about maximum effectiveness.

B. Teacher Training

The pre-service curriculum in teacher training should have the following features:

1. A sound and strong training in modern trends and approaches in the biological sciences. This should be supplemented by adequate background knowledge in related subjects, including chemistry, physics, mathematics, geology, etc.
2. A basic psychological education.
3. A training in exercising different teaching methods including field techniques, laboratory skills, classroom management and administration, and in the use of various teaching aids.
4. A training in the organization of subject matter at different levels of complexity.

5. Instruction in the proper use of audio-visual methods and new technical developments in teaching aids.
6. Training on evaluation of the achievements of pupils and the effectiveness of his own teaching and training on evaluation of curricula, books and various instructional materials.

The following should be considered as in-service and refresher training courses:

1. Refresher courses which bring teachers up to date on the points recommended under the pre-service curriculum should be organized. It is desirable for a teacher to keep himself abreast with modern trends in the biological sciences and should attend such courses as often as possible.
2. Opportunities should be provided whereby teachers may acquire further experience in research and enable them to perform research on their own.
3. Seminars, workshops, conferences, etc., may be held whereby exchanges of ideas and experiences are brought among biology teachers in a locality, region, country, and different countries.

III. On Evaluation in School Biology Teaching

1. A scheme of work, or curriculum, should be evaluated, aims examined and content analyzed, before being generally accepted. It should be tried out in the classrooms and evaluated in terms of feedback from teachers and pupils.
2. Formative evaluation should be major consideration in the development of curriculum materials.
3. Evaluation should consider techniques other than written tests and examinations, such as, observations

of student behaviour, interviews, and development of skills through performance tests.

4. Evaluators should be acquainted with the objectives of the course, which should be explicitly stated so that in evaluating materials or student achievements, attention is directed towards both the content and the processes of science; in the construction of tests a tridimensional grid can be developed to help guide the evaluation.

5. Teacher should be oriented on the philosophy of evaluation which will consider the broader aspects of evaluation. More specifically, training should be provided on test construction, with particular emphasis on test items which tend to measure not simple recall, but comprehension, ability and skill in analysis of data, application, and other processes of science. Such training should be provided in both pre-service and in-service levels of teacher education.

6. Well-designed test items, developed by experts (subject specialists, teachers, and psychometricians) should be made available to teachers to serve as models, the teachers should be encouraged to develop his own battery of tests for his particular course.

7. The foregoing recommendations should be made available to all those involved in various aspects of evaluation, such as, the administrators of national examinations, school administrators, educational organizations, and teachers.

8. A committee or an organization should be formed to enable developers of curriculum materials to meet and exchange information and ideas on the improvement of evaluation practices.

IV. On the Relation of School Biology to Post-School Biology and Everyday Life

1. The content of the course should be comprehensive enough for students and should take into account the immediate socio-economic environment. The course should aim at developing appreciation of nature and at the intellectual, aesthetic and utilitarian values of biology.
2. The content should take into account the main areas of biological science as well as the recent advances in these areas. Adequate emphasis should be on both the content and processes of science. The main themes of the course would be biology as an inquiry, and the historical development of biological concepts. These schemes should be all pervasive.
3. Ways and means should be found to make the pupils appreciate the "nature of biology, its modes of inquiry, its major theories and conceptual inventions," through activity, inquiry and discussion. As much as possible the facts and problems immediately connected with the country's welfare be used as materials of instruction.
4. The laboratory should be the focal point of all instructional activities which must be investigative.
5. The links between pure and applied biology are close and lines are not easily drawn. Applications of biology help to make biology teaching

more lively and relevant to every day life, and in a developing country applied biology is vital and should be taken for granted.

V. On the Role of the University and Other Agencies

It is recommended that there should be effective communication among scientists, science educationists, teachers and students in the secondary schools. Possible ways of achieving this communication are the following:

1. Advising on the development and design of biology programmes to be taught at secondary levels. This may take the form of curricular revisional adaptations or reorientations of emphasis so as to meet local requirements and conditions.
2. Stimulating use of effective teaching methods.
3. Coordinating programmes for biology teachers in training college.
4. Advising on examinations.
5. Conducting refresher courses.
6. Supporting researches and awarding scholarships, including the international exchanges of secondary school teachers in order to enable them to study new developments and observe classroom instruction.
7. Publishing articles on biological researches and experiences of educationists relating to biological education.

APPENDIX 2

ESTABLISHMENT OF AN ORGANIZATION ON SCHOOL BIOLOGY TEACHING IN ASIA

I. Justification

The recently concluded conference on school biology teaching in Asia has strengthened the conviction among the many participants of the need for an organization that will, among other things, permit a continuing exchange of ideas, information, and materials relative to the improvement of school biology teaching in Asia. Such an organization, it is felt, would serve as a vehicle for following up, implementing recommendations and stimulating the initiation of action programmes among the participating countries.

At the last session of the conference, an executive committee of five was elected to assume the responsibility of setting up such a regional organization on school biology education.

The following were elected:

Chairman: Dr Liceria B. Soriano, Bureau of Public Schools, Manila, Philippines

Executive Dr. Dolores P. Fernandez,

Secretary: Science Teaching Centre, University of Philippines, Quezon City, Philippines.

Members: Prof. Hilary Cruz, Department of Zoology, University of Ceylon, Peradeniya, Ceylon.

Prof. B. M. Johri, Department of Botany, University of Delhi, Delhi, India.

Dr. Kazuhiko Nakayama, Graduate school of Education, International Christian University, Tokyo, Japan.

In view of the foregoing considerations, it was decided to submit this proposal for assistance to establish an Asian Organization on School Biology.

II. Objectives

1. To establish an organization, a major function of which would be to follow up the recommendations and resolutions of the First Asian Conference on School Biology through the participating countries and those which did not participate.
2. To establish a clearing house for information regarding school biology programmes from various countries.
3. To prepare for the next conference on school biology to be held in Tokyo, Japan.
4. To have an organization which will assist in the exchange of biology professors among different countries, particularly the exchange of experts in biology teacher in-service education.

Further comments on statement of objectives:

1. Follow-up work would include such activities as drawing up a mailing list of Asian biology educators, contacting people in Asian countries who are in positions to effect changes in school biology teaching, preparing and securing suggestion from biologists and educators on possible topics for discussion and study at the next biennial conference, setting up a secretariat for this organization, plans for holding periodic (biennial) conferences.

BIOLOGY IN INDIAN HIGH SCHOOLS

2. The clearing house should not just be a data centre but, hopefully, it should be an active centre for new thinking in the area of school biology. A newsletter published by this clearing house would keep the member countries informed of developments in the different countries.
3. It is expected that five members of the Executive Committee (or their representatives) will meet in Tokyo, Japan, in December, 1967 to plan the next biennial conference. At this planning conference, a tentative programme for Tokyo conference and details pertaining to it will be discussed. It should also be possible at this planning conference for the Executive Committee to discuss matters pertaining to objective 1 and 2.
4. The organization should consider means of bringing biology teachers from other countries to assist in running institute programmes for biology teachers. From such exchanges, publications on teacher education materials suitable for

Asian countries may result.

III. Plan of Operation

1. The temporary location of the organization will be:
Science Teaching Center
University of Philippines
Diliman, Quezon City
2. Each member of the Executive Committee will receive a copy of each official letter or communication of the organization so that each is continually informed of details of operation and other matters pertaining to the organization.
3. The Executive Committee will select a name for the organization and draft a constitution, which will then be submitted to the other members (participants at the conference) for approval.
4. As soon as the secretariat has been set up in the Bureau of Public Schools or the Science Teaching Centre, the Philippine members of the Executive Committee will take the initial steps to implement the objectives of this proposal.

Biology in Indian High Schools

B.M. Johri and Manohar Lal

(Résumé)

Le rôle des Biologistes Indiens consiste en premier lieu à moderniser les programmes et les méthodes d'enseignement de la Biologie et à convaincre les autorités de l'impact de cette science sur la vie économique du pays.

Actuellement l'enseignement de la Biologie est encore fort réduit et de style traditionnel : l'accent est mis sur la morphologie, l'anatomie ..., les parties physiologiques, écologiques ne figurent que pour une partie infime du programme. Les ouvrages sont pauvres, non adaptés aux pays et utilisent de nombreux termes techniques. L'expérimentation est minime. Les enseignants, en raison des faibles salaires, sont peu nombreux et surchargés. Leur enseignement reste stéréotypé.

Des réformes importantes sont envisagées, certaines fonctionnent déjà depuis quelques années et donnent toute satisfaction. Elles consistent surtout en une approche moderne des problèmes ; des ouvrages adaptés aux besoins sont édités, des laboratoires sont développés et équipés.

Des moyens nouveaux sont mis en jeu : création d'aides enseignants, échange de professeurs avec l'étranger, surtout avec les U.K., U.S.A. et Canada ; cours à la télévision devant aider les professeurs dans leurs leçons ; création de clubs en vue d'intéresser les jeunes élèves à l'étude des sciences, semaines scientifiques réalisées au niveau du district, de l'état, de la région, permettant la mise au point des programmes, sélection des étudiants capables de faire des études scientifiques (compétition, études de projets) ; formation des enseignants et recyclage durant l'été.

Ces moyens doivent permettre, à l'aide du temps, l'assimilation et la diffusion des connaissances nouvellement acquises.

La biología en las escuelas secundarias de la India

B.M. Johri y Manohar Lal
(Resumen)

La función de los biólogos indios consiste en primer lugar en modernizar los programas y los métodos de enseñanza de la biología y en convencer a las autoridades de la influencia de esta ciencia en la vida económica del país.

Actualmente, la enseñanza de la biología es todavía muy reducida y de tipo tradicional: se hace principalmente hincapié en la morfología y la anatomía, mientras que la fisiología y la ecología no constituyen más que una ínfima parte del programa. Los libros son deficientes, no están adaptados al país y utilizan numerosos términos técnicos. La experimentación es mínima. El personal docente, debido a los bajos salarios, es poco numeroso y tiene un trabajo excesivo. La enseñanza es rutinaria.

Se proyectan importantes reformas y algunas se aplican ya desde hace años de un modo satisfactorio. Las innovaciones consisten principalmente en un enfoque moderno de los problemas, en la publicación de obras adaptadas a las necesidades y en la instalación de laboratorios.

Se están aplicando nuevos medios, tales como el nombramiento de auxiliares, intercambio de profesores con el extranjero, sobre todo con el Reino Unido, los Estados Unidos y el Canadá, los cursos por televisión para ayudar a los profesores en sus lecciones, la creación de círculos para interesar a los jóvenes alumnos en el estudio de las ciencias, la organización de semanas científicas de distrito, de estado y de región para la preparación de los programas, la selección de los estudiantes dotados para los estudios científicos (competiciones, redacción de proyectos), la formación de personal docente y los cursos de perfeccionamiento durante el verano.

Esos medios deben permitir, al cabo de cierto tiempo, la asimilación y la difusión de los nuevos conocimientos adquiridos.

THE CAAS SCHOOL BIOLOGY PROJECT

H. Crusz*

The Education Department of Ceylon has been engaged since 1957 in revising the methods of science teaching in schools and in developing curricula suitable for use in Ceylon. A science teaching development programme was inaugurated with UNESCO assistance. It was in fact "a manifestation, in the specific area of science education, of the felt need for change prevalent in Ceylon, and in other parts of the world." The Department expressed the view that assistance and cooperation in curriculum revision would be welcome, especially if it originated within a group such as the Ceylon Association for the Advancement of Science.

INAUGURATION OF THE SBP

In 1961, the Asia Foundation took the initiative of asking the CAAS whether it would be interested in receiving financial support from the Foundation for the purpose of designing a science course suited to Ceylon schools. A CAAS committee discussed the question and recommended that the CAAS should welcome this support and take the opportunity of examining the school curriculum in the specific field of biology, for in no other field was school teaching so intimately bound up with the actual environment of the pupil. In order to be more specific and practical, the committee recommended that the CAAS should set up a project for revising the biology curriculum at the GCE (ordinary level) (i.e., 9th and 10th standards). This level of school biology teaching was chosen because it was a terminal one for most pupils (only 5% of them proceed to higher education in science) and also because the Education Department had already completed, with UNESCO assistance, a curriculum revision project for General Science in pre-GCE classes.

The Education Department was also preparing its own school curricula for GCE (G.L.) science subjects including

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biology, and these were to come into operation from 1964. Those new curricula (in Physics, Chemistry and Biology), prepared by the Department's own staff, have been in use in schools since 1964. This did not mean however that the CAAS biology project was superfluous: curriculum revision is not something that can be done once and for all, and much basic work remains to be done. The Education Department is represented on the CAAS School Biology Committee by the Assistant Director-General who is in charge of science education, and by the Chief Biology Inspector. The Department generously grants equipment worth up to Rs. 20,000/ — per annum to the project.

The Committee estimated that such a project would require at least 3 years of work and cost about Rs. 325,000/. Negotiations with the Asia Foundation went on till 1962 and the estimates were reduced to Rs. 218,700/ — and the Foundation finally agreed to make a grant of Rs. 217,000/—.

In 1963, a special committee for the project was formed. Government approval of the preferred grant from the Asia Foundation was obtained and steps were immediately taken to fill the post of Director of the project. The post was duly advertised and applications called for in the local press.

As none of the applicants was found to be suitable, Dr. Valentine Basnayake, Senior Lecturer in Physiology in the Faculty of Medicine, University of Ceylon, was invited to be Director of the Project and Secretary to the Committee. Leave of absence for this purpose was sought and obtained from the University of Ceylon for Dr. Basnayake by the CAAS.

The Project officially commenced work on 1st January, 1964, and came to be called the CAAS School Biology Project. The 15-member committee, which is an honorary one, is composed of at least one of each of the following: — botanists, zoologists, agriculturists, school biology teachers, representatives of the Government Education Department and laymen interested in science, Dr. S. W. Bibile, Professor of Pharmacology in the University of Ceylon, was elected chairman of the committee.

AIMS

The main purpose of the project, as broadly stated in its constitution and rules, is "to show ways and means of improving the teaching of biology in Ceylon schools, particularly at GCE (G.L.)." The project was to pay special attention to: (a) the use, wherever possible, of local biological materials in teaching biological types and functions, (b) the imparting to the pupil, within the framework of contemporary biology, of an understanding of the processes of science, rather than the teaching of a mere body of facts and theories, (c) the use, wherever possible, of simple, inexpensive apparatus which can be made in the school itself, (d) the formulation of a detailed scheme of work (and ancillary material) for teaching and learning biology at GCE (G.L.) in Ceylon schools and (e) cooperation with teachers so as to create a group of persons who are keenly interested in translating into practice the aims of the project.

The questions of evaluation was also considered although no specific provision was made for it at that stage.

During the deliberations of the committee at its almost uninterrupted series of monthly meetings, various aims and concepts relating to school biology teaching were thoroughly disseminated by means of working papers; these were discussed and accepted unchanged or in modified form, or rejected, in the light of these discussions. All these deliberations were duly minuted.

An important feature of the work done was the modification in thinking and action that took place in the light of new experience as the project went under way. Some of the matters carefully considered were (1) teaching attitudes in science education, (2) principal biological principles (3) aims of the project (see appendix I), (4) analyses of syllabuses, (5) sequence of topics in teaching school biology, (6) current curriculum revisions in other countries, and the adaptation of BSCS materials, (7) the biological aspects of the public services in Ceylon (see appendix II), (8) the Director's report on his study tour abroad.

Discussions of this last item was an important one and a direct consequence of Dr. Basnayake's study tour abroad

in July-September, 1964, on which he submitted a comprehensive and stimulating report to the committee. During this tour Dr. Basnayake was able to study, among other things, the new school curriculum developments in the U.S.A. as well as BSCS adaptation work in Tokyo, Manila and Bangkok. He had also planned to visit the Nuffield Biology Project in Britain, but, unfortunately, the Project was not in a position to accommodate his visit at that time. The tour was financed by the Asia Foundation and the U.S. National Science Foundation.

Discussion of Dr. Basnayake's report resulted in several changes being made during the subsequent course of the Ceylon project, changes which entailed a revision of the original estimates (without prejudice, however, to the total cost of the project). It also involved a doubling of the estimated time required for the completion of the project.

The Director also visited in 1964 a number of Ceylon schools in order to study school biology teaching at first hand.

BSCS ADAPTATION

Very early in the series of SBP meetings, the BSCS materials, which have aroused such world-wide interest among educators and biologists, were studied and discussed. The question arose whether the School Biology Project should adopt this excellent material with suitable adaptations for Ceylon or whether it should produce its own indigenous materials. The question was discussed at length and it was decided to develop an indigenous course "while taking advantage of the literature."

In this connection, the experience gained by the Director during his study tour, and Dr. Arnold Grobman's visit to Ceylon in February, 1965, at the request of the School Biology Project, helped considerably in clarifying matters. Dr. Grobman, during his visit, clarified the interpretation of the term "BSCS Adaptation" in these words: "It seems to me that there is a continuum which might be characterized as follows:

1. Use of BSCS unchanged in an overseas country — usually undesirable.
2. Use of a BSCS version as the basic model for a new book in the overseas nation with such changes introduced to adapt it for the biota, educational system, culture, age and background of students, special needs of the students, time available and experience in related courses. This, with few or many changes, would constitute adaptation and is desirable. Here we could give maximum help.
3. Creation of a "de novo" "indigenous" book in the overseas country with examples, illustrations, etc. picked up from any useful external source including the BSCS. This is a desirable approach although one might question the wisdom of a small country investing the tremendous effort to accomplish this. We could be of some help, if requested, but not to the extent for an adaptation. In essence, this approach is simply the writing of a new and independently conceived book, with its own philosophy, but taking advantage of the literature.
4. Creation of a new book completely independent of any other existing materials. This would seem to be undesirable — in any event, the BSCS would not be participating.

Basnayake felt, according to the scale of 1 to 4, that his work would be approximately 2 1/2. We let it go at that. ("I believe it will turn out to be closer to 2 than to 3.")

One of the overriding reasons for the School Biology Project developing an indigenous course "while taking advantage of the literature" was non-acceptance of the general BSCS view that applied science and technology should by and large be omitted from school science courses. The School Biology Projects however took the view that the links between pure and applied biology were close and that the lines were not easy to draw; that applications of biology must help to make biology teaching more lively and relevant to everyday life and that in a developing country like Ceylon ap-

plied biology was vital and could not be taken for granted. The teaching of applied science in however "dilute" a form, at GCE (O.L.), was thought to be very necessary if the country's citizen were to be made more technology conscious.

All this does not mean that the inculcation of a "spirit of inquiry" should find second place in school biology teaching. It only means that the course should not be made lopsided by giving overriding importance to it. The concept of science should also include the concept of a "body of knowledge" and this knowledge should be not only of the more universal kind but also of the kind that is eminently suited and relevant to the life and needs of the country.

SBP CURRICULUM MATERIALS

Under BSCS inspiration it was originally intended to produce: (1) a Teacher's Guide, (2) Student Exercise, (3) Student Text, and (4) Supplementary material, in that order. The *Teacher's Guide* and *Student's Exercises* were started simultaneously, as it was felt that these needed high priority.

As in the case of the writing of the BSCS materials, but scaled down in relation to the funds available, these materials were prepared by a writing panel composed of university teachers and school teachers.

The advantages expected from such a cooperative effort were the competence and up-to-dateness of the materials, the promotion of cooperation between school and university, and the increased acceptability of the materials to schools. Various topics were assigned to the writers. Each topic was written by a university teacher and a school teacher, with the Director acting as coordinator. To guide the writers in the inclusion of material on applied biology, a working paper on "The Biological Aspects of the Public Services" was prepared by the Director and discussed at several meetings (for a revised draft of this working see Appendix II).

The writing of a *Student Text* never got off to a start for two main reasons: firstly, the writing of the *Teacher's Guide* and *Student's Exercises* took much longer than

anticipated, and secondly, the *Student Exercises* came to include such material (in the manner of BSCS Special Materials) that a *Student Text* was thought to be not immediately necessary.

The supplementary material produced so far consists of:
(a) Gleanings from biological work in Ceylon; (b) Problems.

TEACHER'S GUIDE

This is very nearly complete. The format adopted is that of the BSCS Special Materials Teacher's Guide. This format was chosen because it was considered that (a) class teaching should be by discussion and activity, (b) school teachers in GCE, (O.L.) classes in Ceylon are mostly non-graduates (c) the Teacher's Guide should exemplify for the teachers how the class discussion could be conducted and (d) biology being essentially a system of concepts or ideas, these latter should be explicitly spelt out and the teaching of them, by discussion and activity, exemplified.

STUDENT EXERCISES

This was prepared alongside of the Teacher's Guide by the same writing panel. The material consist of laboratory exercises, readings, analysis, programmed material, quizzes, drawings, graphs, maps, and cartoons. For much of this material the SBP is heavily indebted to the BSCS materials including the Philippine adaptation of the BSCS Green Version.

The term "analyses" is used here to mean reading material where questions are asked all along the way, the answers being provided on the last page of the reading or in the *Teacher's Guide*. It is in fact a reading which calls for more active participation on the part of the reader. The idea was taken from the BSCS treatment of "auxin action" but was carried much further in the SBP's *Student's Exercises*.

GLEANINGS FROM BIOLOGICAL WORK IN CEYLON

This volume was prepared by the Director. It consists of 200 pieces of varying length, extracted from books and journals, and dealing with biological work that has been

done in Ceylon. It is intended to serve as supplementary material for the course and to give added expression to one of the main aims of the project, namely to teach GCE (O.L.) biology with special reference to Ceylon.

PROBLEMS

A volume under this title has been prepared by the Director. It is a new type of educational material for GCE (O.L.) biology, modelled on the BSCS "Invitations to Inquiry." However, it differs from the 'Invitations' in the following respects: (1) it uses only actual data; (2) the data have been drawn from published biological work done in Ceylon, or, in a few cases, from work done outside Ceylon but of close relevance to Ceylon; (3) its aims are less single-minded, e.g., some of the material is intended for use in teaching certain biological concepts and not only for the discussion of scientific methods in biology. It also aims at showing biology as a study which is relevant to Ceylon; (4) there is no careful gradation of "Problems."

The material in Problems can be put into three groups: (a) teaching material for the (initial) teaching of certain biological concepts; (b) reinforcing material for strengthening the understanding which pupils have of biological concepts which have already been taught, and (c) extra material for use as mental exercises in scientific method.

All the above materials have been regularly scrutinized and revised at joint meetings of the School Biology Committee, writers, and teacher participants.

USES OF THE SBP MATERIAL

These materials are at present in mimeographed form. It is planned to use them in classroom teaching from 1967, in order to judge the feasibility of using them in Ceylon classrooms. The *Student Exercises* will be translated immediately into Sinhalese and Tamil for this purpose. All the material will subsequently be revised in the light of these trials.

The Education Department has requested the School Biology Project to make an advance release of certain

portions of the SBP materials (including the *Student's Exercises, Gleanings and Problems*) for use in Ceylon Schools.

MINIMUM STAFF REQUIREMENTS

The staff of the School Biology Project consists of: director, a typist-clerk, an artist-photographer and a laboratory assistant. In the Director's opinion, this staff has been found to be quite insufficient for expeditious work.

The minimum requirements, according to him, for a curriculum project of this nature would seem to be:

1. A director who would plan, coordinate and edit;
2. An assistant to look after the literature and supplementary reading;
3. A laboratory supervisor (an experienced science teacher or science inspector) to try out experiments old and new;
4. An artist-photographer;
5. A typist-clerk;
6. A publications officer to do the routine work of securing photographs, copyrights, printing etc.
7. A writer for re-writing the material expeditiously.

Appendix I

CEYLON ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE CAAS SCHOOL BIOLOGY PROJECT

Working Paper 8a. A concise statement on the aims of the
School Biology Project

B.J.P. Alles and V. Basnayake

The aims listed below are intended to serve as tentative guide lines for the construction of a scheme or schemes of teaching biology at G.C.E.O. Level in Ceylon schools for pupils in the age range 14 to 16 and with a normal ability distribution.

The list is in three parts. Part 1.000 states the aims in relation to "Knowledge," part 2.000 in relation to "Skills," and part 3.000 to "Attitudes & Values."

The numerals I, II, III and IV which are found in a column on the right hand side of the page indicate the relative degree of importance attached to the various aims, according to the following scale:

- I. Aims to be pursued intensively *and* pervasively.
- II. Aims to be pursued intensively where possible or pervasively.
- III. Aims to be pursued when opportunities offer.
- IV. Aims postulated but rarely directly pursued in the teaching scheme owing to a variety of reasons and circumstances which include:
 - subtlety of subject matter, skill, etc.;
 - inconsistency with the level of maturity of the pupil;
 - limitations of resources (apparatus, literature, etc.)

A I M S

PART 1.000 KNOWLEDGE

- 1.100. To assist the pupils to acquire a knowledge of:
- 1.110. The main groups of living organisms, with a view to giving the pupils a knowledge of *diversity of type* as exemplified by the following

<i>Plants</i>	<i>Fungi & Bacteria</i>	<i>Animals</i>	
dicotyledons		mammals	
monocotyledons		birds	
gymnosperms		reptiles	
pteridophytes		amphibians	
bryophytes		fishes	
algae		molluscs	
		arthropods	
		annelids	
		echinoderms	
		nematodes	
		platyhelminths	
		coelenterates	
		protozoa	III

- 1.120. the *main types of communities of organisms* and their interrelationships with the environments. III
- 1.130. the *processes* which are associated with the life of mature organisms — with special reference to man, but also to lead to a recognition of the *unity of life*. These processes include —
- | | | |
|-------------------------------|------------------|----|
| excitability | excretion | |
| nutrition | coordination | |
| respiration | locomotion | |
| transport within the organism | barrier function | II |
- 1.140. growth and form in organisms, including development and metamorphosis. III
- 1.150. the process of *continuation of the species*, including reproduction and heredity. III
- 1.160. the *evolution* of living organisms III
- 1.170. the behavior of living organisms, including reflex action, habit and instinct. III
- 1.180. biology as:
- 1.181. a process of *scientific inquiry* ultimately giving the pupils a basic understanding that can be developed into a knowledge of the process at scientific inquiry, including observation, observation under controlled conditions (experiment), classification, recognition of laws and generalizations, hypotheses and theories, and the communication of results. I
- 1.182. a product of the work of *persons* of different *periods* and *countries*. III
W.P.8a
- 1.183. a science that *borrow*s from other branches of science and knowledge, such as chemistry, physics and mathematics, in order to advance. III

- 1.190. biological processes of *socio-economic importance*, including parasitism, immunization, and conservation of natural resources. III
- 1.200. the knowledge referred to above will be treated.
- 1.210. in *wide perspective*, as indicated by the mature and variety of topics given above. II
- 1.220. in a *degree of depth and detail* which is appropriate to the level of *maturity of the pupils* and yet not inconsistent with the wide perspective referred to in 1.210. II
- 1.230. so as to give the pupil a *contemporary outlook* and appreciation of biology. III
- 1.240. with special reference to Ceylon. I

PART 2.000 SKILLS

- 2.010. simple *observations* with and without observational aids. I
- 2.020. *collecting* and *storing* biological material III
- 2.030. *assembling* apparatus and *performing* simple experiments, including the simple *design* of experiments. II
- 2.040. *recording* observations and experimental results, including —
 - 2.131. representation through transverse longitudinal sections, etc.
 - 2.132. numerical and graphical representation. III
- 2.050. *reconstructing* from the recorded results a three-dimensional conceptual structure. III
- 2.060. the use of *symbols* and *formulae*. III
- 2.070. *classification* and the use of keys. III
- 2.080. *formulating problems, hypotheses* and *theories*, and testing them for validity. I

- 2.090. applying biological knowledge in *everyday life* situations, including maintenance of health, selection of food, etc. III
- 2.100. getting relevant information by *using reference material*. III
- 2.110. *communicating* the results of scientific investigation. IV
- 2.120. *evaluating evidence*.

PART 3.000 ATTITUDES

- 3.100. to give the pupils an appreciation of the value of all the items listed under *knowledge* and *skills* above. As in parts 1.000 and 2.000.
- 3.200. to assist the pupils to acquire:
 - 3.210. a *love* and *respect* for living organisms II
 - 3.220. an *appreciation* of the value of natural resources. III
 - 3.230. a taste for further inquiry and study. III
 - 3.240. an attitude of mind which —
 - 3.241. *asks for evidence* before accepting assertions (and suspending judgment until appropriate evidence is available).
 - 3.242. recognizes that biological knowledge *is not final* and that many questions are *as yet unanswered*. III

Appendix II

CAAS SCHOOL BIOLOGY PROJECT

Working Paper 37a. Biological Aspects of the Public Services

THE CASE FOR including an outline of the biological aspects of the Public Services in the SBP course content can be summarized as follows:

1. The general aim of the Public Services is to promote the welfare of the community.
2. The Public Services cost a great deal of money, and a citizenry that understands the aims and methods of the Public Services is a potent factor in the successful execution of these Services.
3. The biology course offers many opportunities for improving the future citizen's understanding of the Public Services.
4. The pupils' appreciation of the relationship of biology to human life will probably be greater if the biological aspects of the Public Services are included in the course.

THE CASE AGAINST including the topic in a biology course can be summarized as follows:

1. It further lengthens an already long course.
2. It may give the pupils a lopsided utilitarian view of biology.
3. It possibly opens the door for politicking.
4. It is so much "chalk talk."
5. The material is frightfully tentative.

THE PLACE in the course could be:

- (a) at the end of the course —
 - i. as a separate section.
 - ii. embedded in revision material.
- (b) at various points throughout the course, as “plug-in” material.
- (c) as supplementary reading material.
- (d) as a combination of the above.

THE BIOLOGICAL PRINCIPLES referred to in subsequent pages refer to those stated in W.P. 16.

Biological Principle I. *Living things display a characteristic combination of properties, the most important of which are —*

- (i) *organized structure*
- (ii) *excitability*
- (iii) *the ability to use food for growth and energy (metabolism), and*
- (iv) *the ability to reproduce their kind.*

Application 1. Food spoilage is often due to the activity of organisms. These organisms have certain requirements in order to grow and multiply. Methods of food preservation abolish one or more of these requirements.

Application 2. In some vaccines, the micro-organisms are dead (killed); in others, they are alive but of low virulence.

Application 3. Certain first aid procedures recognize that it is not always easy to determine whether a man is dead or apparently dead.

Biological Principle II. *The structural unit of life is in many cases the cell, and in all cases, nucleoprotein.*

Application 1. The examination of cells and tissues is an important diagnostic method in medicine.

Biological Principle III. *In spite of the great variety of life, living things can be classified into a relatively few main categories.*

Application 1. The work of classifying is a necessary activity for the identification of organisms. The national museums, research institutes and universities are repositories of biological specimens and reports.

Biological Principles IV and V. *In spite of the great variety of life, the chemicals found in bulk in most kinds of living things can be put into a few main groups, namely, carbohydrate, liquid, minerals, protein. There are catalysts for every chemical reaction associated with life; they are called enzymes.*

Application 1. Man exploits the chemical substances found in organisms.

Application 2. Metabolic blocking agents are put to many uses (including medical uses).

Application 3. Man exploits the metabolism of microorganisms.

Application 4. Enzymes play an essential role in some industrial processes.

Nutrition

Application 1. The nutritional condition of a population is estimated by examining the diet and the medical condition of a sample of the population.

Application 2. Nutritional surveys have shown that there is much undernutrition and malnutrition in Ceylon. Periodical nutritional surveys are necessary in order to assess the nutritional progress of the population.

Application 3. It is possible to devise formulae for a cheap and nutritious diet for the population.

- Application 4.* Ceylon is self-sufficient to her nutritional requirements of vegetable fat, but not for those of carbohydrate and protein.
- Application 5.* Milk and milk products are important foods.
- Application 6.* The rice ration has been worked out on the basis of certain assumptions.
- Application 7.* Some vegetables are nutritionally rich, while others are worthless.
- Application 8.* Not all oils are of equal nutritional value.
- Application 9.* Patent medicines are unnecessary for normal persons under ordinary conditions.
- Application 10.* Some foods may contain poisonous substances.
- Application 11.* Milling and parboiling have important effects upon the nutritional value of rice.
- Application 12.* Cooking is often a pre-digestion of foods. It has certain other advantages, and also disadvantages.

Biological Principle VI. *The individual organism can be analyzed into components in which structure and function are intimately related.*

A. *Barrier (Tegument).*

- Application 1.* Leather is made from the dermis of animals.
- Application 2.* The main functions of clothing are psychological. Clothing has some physiological functions as well. Clothing is made from natural or artificial fibers.

B. *Input & Output System.*

- B1. *Alimentary.* See also Nutrition
- B2. *Plants.*

- Application 1.* The nature of the soil and the availability of water (by rainfall or irrigation)

are decisive factors in the agricultural potential of land.

- Application 2.* The care of the soil includes manuring, soil conservation, water conservation, crop rotation, etc.
The system of chena cultivation is not an efficient system in areas with dense populations.

B3. *Respiratory.*

- Application 1.* Ventilation requirements for comfort and health can be roughly specified.
- Application 2.* Respiratory problems arise in aviation, in diving, and in some diseases.
- Application 3.* A water-logged soil affects the respiration of plant roots.
- Application 4.* The chief causes of anemia in Ceylon are malnutrition and hookworm disease.

C. *Transport.*

D. *Coordination.*

- Application 1.* Conditioning is an important mechanism in habit formation.
- Application 2.* Goiter is common in certain parts of Ceylon. It is usually attributed to an iodine-deficient diet.
- Application 3.* Auxins have agricultural uses as (I) herbicides, (II) promoters of rooting in cuttings (III) promoters of flowering and fruiting.

E. *Locomotor.*

- Application 1.* Games and sport are useful social outlets for muscular activity in man. Physical activity promotes health.

F. *Reproductive.*

- Application 1.* Artificial insemination is used in the breeding of domestic animals.

Biological Principle VII. *Living things arise from parents which resemble them. Asexual reproduction gives rise to offspring which show little variation. Sexual reproduction gives rise to offspring which show greater variation.*

Application 1. Vegetative propagation from high-yielding and disease-resistant plants is an extremely important way of getting high yields in many plants.

Biological Principle VIII. *Growth and development involve processes of cell multiplication, cell enlargement and cell differentiation. Aging and death are not necessarily inevitable characteristics of organisms.*

Application 1. Many natural fibers are used by man.

Application 2. Several plants are propagated indefinitely by vegetative methods.

Biological Principle IX. *Hereditary characteristics are passed from parent to offspring by genes; genes are composed of nucleic acid.*

Application 1. Growth depends on hereditary factors as well as on environmental factors.

Application 2. Artificial selection is an extremely important method of establishing high-yielding and disease-resistant varieties of plants and domestic animals.

Application 3. Hybridization is an extremely important method of establishing high-yielding and disease-resistant varieties of plants and domestic animals.

Application 4. Vegetative propagation from high-yielding and disease-resistant plants is an extremely important way of getting high yields in many plants.

Application 5. "Improvement" of genetic condition of a population is possible, but the application

of this possibility to human population presents difficulties.

Biological Principle X. *Regulation (homeostasis and adaptation). The individual organism shows power of preserving itself in the face of changes in the condition of its existence. Regulatory reactions are shown also by populations of individuals and by communities of organisms.*

Application 1. The defences of the body against disease and more easily broken down under poor living conditions.

Application 2. Thermal comfort increases working efficiency. Building style and air-conditioning have important effects on thermal comfort.

Application 3. "Artificial" immunity to disease caused by microorganisms can be produced by introducing enfeebled or killed microorganisms, or products of these organisms, into the body.

Application 4. The "wisdom of the body" is not enough for health.

Biological Principle XI. *Organisms show interdependence, some of which are essential for the survival of all forms of life.*

As Interdependence:

Application 1. Man sometimes unwittingly tends to upset natural balances. The results can be unwelcome.

Application 2. Biological control, where possible, is a better way of controlling pests than by chemical methods.

Application 3. Man can use his knowledge of interrelationships between organisms and environment for conserving his natural resources.

1. Soil conservation.
2. Water conservation.
3. Forest conservation.
4. Wild life conservation.

B. *Population.*

- Application 1.* Estimates of the population in Ceylon are made by means of a decennial census.
- Application 2.* The population in Ceylon is rapidly increasing in numbers. A rapidly increasing population gives rise to many problems including problems of food supply, land space, and health.
- Application 3.* The main factor which has led to the rapid increase of population in Ceylon is a lowered death rate. One solution that has been proposed for the population problem is the popularization of measures to reduce the rate of population increase.
- Application 4.* The main step which can feasibly be taken for reducing the rate of population increase is to reduce the birth rate.

C. *Community.*

- Application 1.* It is desirable to preserve certain tracts of natural forests from encroachment by man.
The natural forests which have been selected for preservation are called Natural Reserves and Sanctuaries.
- Application 2.* A paddy field is an artificial ecological community.

D. *Succession.*

- Application 1.* Few climax forests are left in Ceylon. It is desirable to preserve at least parts of them from human destructiveness.

E. *Habitat.*

B1. *Land*

Application 1. Ceylon has a series of climatic zones which enables the cultivation of tropical, subtropical and temperate climate crops.

Application 2. The nature of the soil and the availability of water are decisive factors in the agricultural potential of land.

Application 3. The wet plains are almost fully cultivated. The dry plains are agriculturally divisible into upland and lowland zones. Irrigation is necessary for continuous cultivation in the dry plains. The hill country is best suited for certain types of plants and animals.

Application 4. Forests in Ceylon can be classified into wet zone forest, dry zone forest, and montane forest.

E2. *Water.*

Application 1. Inland waters can be used to culture food fish.

Application 2. Continuous research is necessary to improve the yield of fish from the sea around Ceylon.

E3. *Niches.*

Application 1. Many micro-organisms cause disease in plants and animals. They are also often the cause of food spoilage. Most micro-organisms are destroyed by heat and ultraviolet radiation. Other measures which are used to control the activity of these micro-organisms include refrigeration, chemical treatment, isolation of infected material, immunization, etc.

Application 2. Caries and diseases of the roots of the teeth are *preventible*.

Application 3. Examples of striking ecological niches in the body of man are seen in

- (1) the large intestine with its bacterial flora.
- (2) parasitic infestations of the intestine (roundworm, hookworm, etc.) and lymphatics (filaria).

F. Cycles.

- Application 1.* Micro-organisms bring about the decomposition of refuse into harmless or useful substances.
- Application 2.* The composition of refuse is more conservative of nitrogen and minerals than burning refuse.
- Application 3.* Animal and plant refuse must be disposed of in certain ways for the maintenance of the public health.

Biological Field XII. *The stream of life through time has developed from structurally simple beginnings by a process of evolution.*

- Application 1.* The barriers that remain to be broken down between human groups are cultural ones.
- Application 2.* The main agricultural crops in Ceylon are mostly plants which have been introduced from abroad.
- Application 3.* Human society accepts the position that the sick must be tended, and the position that the healthy must be maintained in health and prevented from falling ill.
The most obvious of the preventible diseases are malnutrition and the infective and parasitic diseases.
- Application 4.* Useful measurements of the health of a population include —
- (1) death rate
 - (2) infant mortality rate

(3) birth rate

(4) proportional mortality indicator

(5) expectation of life at birth.

Application 5. The patterns of disease are changing; this is mostly due to the application of recent advances in preventive and curative medicine.

Application 6. The public health services cover the entire span of life.

The CAAS School Biology Project

H. C r u s z

(Résumé)

Dans le cadre d'une révision générale des méthodes d'enseignement scientifique, la Ceylan Association for the Advancement of Sciences a récemment entrepris l'élaboration d'un programme d'étude de Biologie à l'usage des collèges Cingalais.

Le Comité chargé de ce projet a particulièrement souhaité :

- l'utilisation d'un matériel simple,
- le recours à des données biologiques locales,
- la compréhension par l'élève des procédés et des démarches de la biologie, et non plus seulement des seuls faits et théories,
- la rédaction d'un programme d'études détaillé, à l'intention notamment des classes terminales,
- la coopération avec les enseignants pour la mise en pratique du projet.

Ce projet s'est par ailleurs prononcé en faveur d'une adaptation du BSCS au contexte indigène, ainsi qu'aux âges et besoins de l'étudiant concerné, soulignant ainsi l'importance de la biologie appliquée dans un pays en voie de développement comme Ceylan.

Grâce à l'effort conjugué d'un certain nombre d'universitaires et d'enseignants, des ouvrages ont été réalisés à l'intention de ces derniers et de leurs étudiants : exercices, croquis, textes, questionnaires, enquêtes et autres introductions à la recherche biologique.

El proyecto de enseñanza de la biología de la CAAS

H. C r u s z

(Resumen)

Como parte de una revisión general de los métodos de enseñanza de las ciencias, la Ceylan Association for the Advancement of Sciences ha emprendido recientemente la preparación de un programa de estudios de biología para uso de los colegios cingaleses.

El Comité encargado de ese proyecto ha procurado en particular :

- la utilización de material sencillo,
- el empleo de datos biológicos locales,
- la comprensión por el alumno de los métodos y de los intentos de la biología y no solamente de los hechos y las teorías,
- la redacción de un programa de estudios detallado, para uso principalmente de los cursos terminales,
- la cooperación con el personal docente para la aplicación del proyecto.

Además, el proyecto se ha pronunciado en favor de una adaptación del BSCS a las condiciones indígenas y a las edades y necesidades de los estudiantes, subrayando así la importancia de la biología aplicada en un país en vías de desarrollo como es Ceilán.

Gracias al esfuerzo conjugado de cierto número de universitarios y de profesores se ha preparado material para uso del personal docente y de los estudiantes : ejercicios, esquemas, textos, cuestionarios, encuestas y otro material de introducción a la investigación biológica.

KENYA SCIENCE TEACHERS COLLEGE

K S T C

Swedish International Development Authority
Uppsala University

The Kenya Science Teachers College - a college offering a three-year course for the training of teachers for the Kenya secondary schools - is the largest technical-assistance project Sweden has undertaken so far. The aim of the College is to train teachers for pupils in their eighth to eleventh years at school (Forms I - IV in the secondary schools) in scientific subjects (mathematics, physics, chemistry, biology and geography), with a proper adaptation to Kenyan needs. This policy is due partly to the fact that the shortage of teachers in Kenya is particularly marked in these subjects and partly to the fact that Sweden has prospects of recruiting teachers who can give instruction in these subjects.

Like Kenyatta College, Nairobi, the Kenya Science Teachers College is carrying on a new Kenyan type of teacher-training. The Cambridge School Certificate is required for admission to the College. The course is a three-year one and leads to the examination for what is called the S1 Certificate. Teachers with the S1 Certificate cannot replace university-trained teachers, but as there are few university-trained teachers in Kenya, teachers with the Certificate will be responsible for a large part of the teaching in secondary schools for a long time to come. In 1968 and 1969 nearly 50 and from 1970 onwards nearly 100 secondary-school teachers in scientific subjects will take their final examinations at the College each year.

The system of instruction at the College differs in certain respects from that hitherto used in Kenya and the object is to try and stimulate the creation of a more effective system than the previous one. As an example of the new ideas, it may be mentioned that the instruction is organized on considerably more experimental lines than hitherto and that the students study more subjects and get a broader basis for their future teaching work.

During the first few years the College will have only Swedish teachers and during that period Sweden will be responsible for the training of the Kenyan teachers who will eventually replace the Swedes. After five years the teaching will gradually be taken over by Kenyan teachers, so that after ten years all or almost all the teachers will be Kenyans.

The Swedish International Development Authority has delegated the greater part of the administration of this project to Uppsala University, which on 1 May 1965 established a special secretariat for this purpose (the International Secretariat at Uppsala University).

THE COLLEGE STUDENTS, TEACHING SYSTEM, TEACHERS, ETC.

The Students

The students are mainly recruited from the final class of the secondary school (Form IV) and must have a Cambridge School Certificate at a certain minimum standard. Students with other equivalent qualifications are, of course, also admitted.

In both 1966 and 1967, 48 students were recruited annually. From 1968, when the new premises (see below) are expected to be ready, 96 students will be recruited each year, which means that, when complete, the College will have 288 students in 12 classes of 24 students each (four classes for each of the three annual intakes).

The training at the College will also, in principle, be open to students from other East African countries who have suitable previous education. In accordance with the agreement, the Board of the College will determine how many non-Kenyan students can be admitted each year. However, it seems that the accommodation available for non-Kenyan students will be very limited.

The students are encouraged to take part in leisure-time activities and even in the first year several societies were formed at the College - a photographic society, debating society, group of Christian students, etc. The teachers have to be prepared to help with leisure-time occupations - sport, film, shows, talks, etc.

Since the College is residential, the teachers have to take turns at being available at the College also during the students' spare time. A students' library, containing principally scientific literature but also certain other literature, is gradually being built up. Close to the new College buildings, a sports ground is being arranged.

The teaching system

The period of study at the College will cover three years. All instruction is given in English. For the first 18 months all the students pursue the same studies, i.e. they read all the subjects taught at the College, viz. mathematics, physics, chemistry, biology and geography. In addition instruction is given in drawing and English and a certain amount of instruction in methods in each subject. This initial period of study is designed to bring the students up to the subsidiary-subject stan-

dard in all five subjects. It is intended that they shall be able to teach their subsidiary subjects in the lower classes of the secondary schools (Forms I-II). During the second half of the period of study, the students will be allowed to select different combinations of subjects, with two or three main subjects, besides a certain amount of further instruction in English. During the later part of this period about 7 weeks will also be devoted to engineering-workshop practice. Instruction in education theory and practice and a term of teaching practice at a secondary school are also included in the course. It is also intended that each student shall carry out an individual special task in one of the subjects. The period of study is concluded after three years at the College with the examination for the S1 Certificate.

The purpose of the subject arrangement is to try and adapt the instruction satisfactorily to Kenyan needs. This is done by giving all the students instruction in the subjects of geography and biology. These subjects are especially important for a country which has so great a part of its commercial and economic life based on agriculture (about 90 %).

One of the differences in relation to previous practice in teacher-training in Kenya is that the College will give the students a considerably broader basis for their teaching work than has hitherto been commonly the case. The College will train teachers who have as a rule two main subjects and three subsidiary subjects, while previously teachers in Kenya had only one main subject and two subsidiary subjects.

The teaching will be arranged on experimental lines, with many demonstrations and much laboratory work. The teachers who are trained at the College will be assisted by the College even after they have left it, through refresher courses, amongst other things. Thus, the College is intended to be a centre for Kenyan secondary-school teachers in the natural sciences for a long period ahead.

In a couple of the subjects it has proved to be difficult to find suitable textbooks for the courses. The Swedish mathematics teacher has gradually written compendiums covering the first few terms' instruction. He intends to complete this extensive work to cover the whole period of study. The biology teacher has written a compendium entitled "Ecology and some ecosystem in Kenya". In physics also it is difficult to find a suitable textbook. In English a comprehensive series of language-laboratory materials has been prepared.

Kenya Science Teachers College

(Résumé)

Le Collège des professeurs scientifiques du Kenya résulte d'un projet d'assistance technique entre la Suède et le Kenya. Il forme en trois ans des professeurs d'enseignement secondaire pour les mathématiques, la physique, la chimie, la biologie et la géographie.

Pendant les 18 premiers mois les étudiants suivent tous les mêmes cours (en anglais), ce qui leur donne les connaissances nécessaires pour enseigner dans le premier cycle secondaire, puis les 18 mois suivants ils ont le choix entre plusieurs options. Sur cette période environ 7 semaines sont consacrées à une formation technique. Des cours théoriques et pratiques de pédagogie sont prévus ainsi qu'un stage dans un établissement secondaire.

Le système de formation se distingue des systèmes traditionnels par une plus large culture générale donnée aux maîtres, l'emploi des méthodes actives, l'appel aux initiatives individuelles et une ouverture plus grande vers les activités quotidiennes et les besoins du pays.

El Colegio de Formación de Profesores de Ciencias de Kenya

(Resumen)

El Colegio de Formación de Profesores de Ciencias de Kenya es el resultado de un proyecto de asistencia técnica entre Suecia y Kenya. En él se forman en tres años profesores de matemáticas, física, química, biología y geografía para la enseñanza secundaria.

Durante los 18 primeros meses todos los estudiantes siguen los mismos cursos (en inglés), lo que les da los conocimientos necesarios para enseñar en el primer ciclo secundario, mientras que durante los 18 meses siguientes siguen los cursos elegidos entre varias posibilidades. Unas 7 semanas de este periodo se dedican a la formación técnica. Se siguen cursos teóricos y prácticos de pedagogía y hay que hacer un periodo de practicas en un establecimiento secundario.

El sistema de formación se distingue de los sistemas tradicionales por la mayor cultura general que se da a los futuros profesores, por el empleo de métodos activos, por el fomento de las iniciativas individuales y por una adaptación mas grande a las actividades cotidianas y a las necesidades del país.

UNE EXPERIENCE D'ENSEIGNEMENT SCIENTIFIQUE INTEGRE

Y. Cabanis

(Tananarive, Madagascar)

Communication présentée au Congrès de Varna sur l'Enseignement intégré (CIES, septembre 1968)

(Extraits)

Depuis le 15 octobre 1967, une expérience est en cours au Collège d'Enseignement Général d'Antanimena-Tananarive. Elle se déroule dans une classe de 6ème Moderne (c'est-à-dire la classe d'entrée dans cet enseignement) d'un établissement secondaire d'enseignement court... L'effectif de la classe est de 37 élèves (dont 17 filles) répartis entre 12 et 14 ans (moyenne d'âge : 13-15 ans) et comprenant 34 malgaches, 2 indiens, 1 français.

Quatre maîtres enseignent dans cette section [...] :

- un maître assure l'enseignement des matières littéraires (français, histoire et instruction civique) ;

- un autre maître intervient dans toutes les matières scientifiques (mathématiques, sciences naturelles, sciences appliquées et initiation technologique, géographie) ;

- un spécialiste de l'anglais et un spécialiste de malgache participent à la formation des élèves, mais ces deux dernières matières ne sont pas intégrées avec les précédentes.

Le travail de recherche et d'application est suivi et contrôlé par un conseiller pédagogique spécialisé pour chaque discipline.

La répartition hebdomadaire est la suivante (devant la classe entière ou dédoublée) :

Français	9 h (7h/2h)	Initiation technologique	1 h
Histoire	1 h30	Géographie	1 h
Instruction civique	1/2 h	Malgache	3 h
Mathématiques	3 h (2h/1h)	Anglais	4 h (3h/1h)
Sciences naturelles	2 h	Gymnastique	2 h

soit au total : 27/heures/élève/semaine.

Cet horaire n'est pas surchargé et permet aux maîtres de demander aux élèves des travaux personnels (recherche de documents, enquête, exercices pratiques individuels, etc...). De temps à autre (1 ou 2 fois par trimestre) sont organisées des visites ou des déplacements sur le terrain. Les thèmes choisis doivent être exploités par le maître littéraire et le maître scientifique conjointement.

LES MOTIVATIONS

Quelles raisons urgentes et profondes nous ont amené à réviser les conceptions et même le contenu des programmes de la classe de Sixième, programme pourtant déjà adapté en ce qui concerne l'histoire, la géographie, les sciences naturelles ?

1.- Le problème de liaison entre l'enseignement primaire et l'enseignement secondaire.

Le passage d'un cycle d'étude à l'autre a amené de tous temps des perturbations et des complications au niveau des élèves. En effet, les changements de maître, la multiplication de ceux-ci, les méthodes de travail spécialisées pour chaque discipline, la personnalisation de l'exposé magistral, règle d'or de l'enseignement secondaire, exigent une souplesse et une faculté d'adaptation que le jeune élève n'a pas l'habitude de fournir.

D'autre part, il n'est pas inutile de rappeler que les objectifs d'une classe de fin de cycle primaire ne sont pas comparables à ceux de la 6ème, classe d'initiation à une nouvelle tranche de scolarité.

A Madagascar, cette situation de principe est encore aggravée par des conditions matérielles. Le postulant à la Sixième est obligé de changer de cadre géographique et affectif, de milieu social (brassage des couches de la société, rencontre d'ethnies diverses ...) car l'établissement est souvent distant de 50 à 100 km de son point d'origine. Cette transplantation accentue encore la surprise et inhibe les réactions de ces enfants déjà timides et réservés de nature. Ainsi se crée supplémentairement un climat défavorable contre lequel il nous faut réagir impérativement.

Enfin, les classes surchargées (70 élèves représentent un minimum dans une classe primaire en "brousse"), le désir ardent pour les maîtres de conduire leurs élèves au succès, la limite d'âge trop élevée pour l'entrée en Sixième (16 ans) font que les maîtres pratiquent une préparation intensive et peu recommandable qui marque profondément ces jeunes cerveaux.

2.- Le problème de l'adaptation à l'enseignement secondaire.

Au dépaysement environnant s'ajoute les difficultés propres à cette nouvelle phase de la scolarité. Nous rappellerons :

- l'utilisation constante et nécessaire d'une langue véhiculaire indispensable et souvent spécialisée dont il faut acquérir la pratique courante et les nuances ;

- une participation individuelle accentuée aussi bien en classe qu'à l'extérieur (à propos d'enquêtes ou de visites ...) ;

- l'intervention régulière et obligatoire de l'observation et de la réflexion personnelles ;

- la répartition du travail basé sur la semaine et non plus sur la journée ;

- une liberté plus large et une indépendance plus grande dans l'organisation du travail personnel extérieur à la classe (les prévisions sont nécessaires).

L'élève malgache qui souvent mettra plus longtemps à effectuer son travail que son correspondant métropolitain trouvera difficilement le moyen de répartir efficacement sa tâche en fonction du temps disponible ;

- la fragmentation de l'emploi du temps et du passage d'une matière à l'autre.

3.- Le problème de la formation de l'enfant.

Dans chaque discipline, les programmes sont exhaustifs et veulent couvrir tout un ensemble d'époques, de phénomènes et de territoires contribuant à proposer à l'élève un aperçu général et introduisant des synthèses récapitulatives. A l'intérieur de chaque matière, le découpage est conçu pour assurer une progression logique et constructive, permettant d'amener régulièrement l'élève au niveau de connaissances jugées indispensables. ...

Ensuite l'horaire respectif (de chaque discipline) limité, le morcellement inévitable et excessif de l'emploi du temps ne permettent pas l'imprégnation suffisante dans chaque domaine ni l'initiation de l'adolescent aux méthodes fondamentales, au raisonnement personnel, à la compréhension des choses rencontrées, à l'utilisation de l'acquis.

L'héritage des sollicitations du primaire pèse encore lourdement sur ces jeunes cerveaux qui ne réfléchissent pas assez et font trop souvent appel aux seules ressources de la mémoire.

En définitive, nous pouvons affirmer que l'épanouissement de l'enfant ne s'est pas réalisé et qu'il faut éviter de poursuivre dans une voie sans issue ; nous devons par tous les moyens lui redonner confiance en lui, affirmer sa plénitude d'expression et préciser davantage sa personnalité naissante. Recherchons les esprits réfléchis et actifs ; cultivons, avant tout, les plus ouverts.

4.- Le problème de la coordination des disciplines.

Une matière étend son champ d'étude jusqu'aux limites que des conventions et des hommes ont arrêtées presque définitivement. Malgré les changements de programme et les amendements successifs, les barrières subsistent sérieuses et paralysantes. C'est ainsi que trop souvent tel spécialiste ignore les problèmes de son voisin, que les disciplines concourantes deviennent concurrentes. Citons, pour mémoire, les nombreux centres d'intérêt communs à la Géographie et à la Géologie; les rapports mal établis entre l'exposé mathématiques et les vérifications expérimentales, l'isolement du français qui ignore trop les thèmes proposés par les matières complémentaires. Chaque discipline admet une répartition propre, un dosage des acquisitions qui se superposent dans une progression verticale, à l'intérieur de la seule matière envisagée, en fonction des différentes classes du cycle secondaire sans qu'il y ait de dérivation, disons de connexion, dans un plan horizontal vers d'autres branches complémentaires et existant dans les mêmes niveaux d'enseignement.

Citons, ainsi, le cas de la géographie qui, dans nos programmes, aborde dès la Sixième les notions de climatologie et de morphologie terrestre, sujets que les sciences naturelles n'envisagent qu'en classe de 4ème.

Citons encore les nombreux liens qui pourraient exister entre les sciences physiques et naturelles dans l'approche de certains chapitres (charbon, calcaire et craie, pétrole, sel marin ...).

Il y a donc bien un cloisonnement effectif qui supprime toute collaboration, toute mise en commun de thèmes locaux, l'exploitation rayonnante et complémentaire des circonstances locales et de l'actualité (sociale ou économique). Tous les pays en sont riches et Madagascar nous en révèle tous les jours davantage. Le seul obstacle à la recherche reste le temps chronologique qui fait défaut pour la recherche personnelle.

Ce cloisonnement est-il justifiable ? Absolument pas dans son principe et encore moins dans son application lorsque le même maître doit assurer, dans nos C.E.G., deux disciplines convergentes et qu'il va devoir exposer le même chapitre sous 2 angles différents sans se servir de ce qui précède, sans faire le rapprochement, comme s'il parlait le plus souvent deux langages différents.

Il existe d'autres excès, d'autres difficultés inhérentes. Partagé entre l'intention de former des hommes à tous les niveaux et de donner un enseignement complet dit de culture, les programmes ont été élaborés et corrigés ensuite parce qu'ils avaient vieilli. Les modifications successives n'ont pas pu maintenir réellement le lien entre les diverses branches et la structure initiale de ces propositions. Un cloisonnement s'est manifesté à l'intérieur même d'une matière. C'est ainsi que chez nous, en CM₂ (les deux dernières classes de l'école primaire), 6ème, 3ème, Terminale D. La germination (avec l'inévitable haricot) au moins quatre fois: au CM₁, CM₂, 6ème et Terminale D. Il y aurait d'autres exemples !

C'est pourquoi il est logique avant d'entreprendre toute réforme, de réfléchir à toutes les associations possibles et de réaliser tous les regroupements souhaitables, et de penser à préparer des structures plus larges et plus conformes à la réalité scientifique actuelle.

5.- Le problème de l'introduction de réformes et de tendances nouvelles.

L'évolution des connaissances et des idées, les acquisitions de la technique moderne, ne doivent pas rester étrangères aux leçons que nous présentons car, en dehors du fait qu'elles sont utiles à l'homme, elles deviennent appliquées ou même fréquentes, dans la vie courante. Nous devons les rendre assimilables à nos élèves, particulièrement dans des pays jeunes où elles pourront stimuler le progrès et le développement de la nation, activer l'émancipation de l'individu vis-à-vis de son milieu traditionnel.

Selon l'expression de M. le Professeur Heller, il est nécessaire de "focaliser sur un point" pour éviter toute dispersion, de restreindre mais d'approfondir les thèmes que nous voulons développer. C'est pourquoi il ne faut négliger aucun aspect du problème posé. Des précisions technologiques et techniques seront données si nécessaires afin de compléter la connaissance et l'exploitation d'un phénomène. Cela suppose donc que des assouplissements, des inflexions soient apportés au programme traditionnel pour aboutir à un enseignement scientifique plus intégré au pays et plus utile aussi. Il n'est plus question de rester académique et conformiste, pas plus qu'il ne serait juste de basculer dans la technologie pure et l'agriculture pratique.

6.- Le problème de l'information.

Nous avons affirmé et démontré que la formation précède l'information et conditionne celle-ci. Il ne faut pas oublier cependant que la formation n'est qu'un moyen de parvenir à l'information et à la compréhension totale.

L'approche d'un sujet, la tentative de redécouverte est une étape de la connaissance fondamentale. L'élève qui suit des études doit avoir envie de poursuivre son travail pour augmenter sa documentation et développer son raisonnement et sa réflexion. L'information appelle l'information ; tout est affaire de progression, d'enchaînement logique et de temps d'exposé - Là encore, il est nécessaire de réviser, de remanier ou de reconstruire.

Après examen de ces différents points, il nous a paru nécessaire que la classe de 6ème soit et reste :

- une classe de transition ;
- une classe de recyclage et de remodelage de la pensée et de l'attitude de l'enfant ;
- une classe d'épanouissement et de sélection pour l'avenir de l'élève et sa scolarité future.

LES APPLICATIONS A LA SIXIEME

Le travail de recherche pédagogique et d'application se déroule actuellement. Chaque maître principal (littéraire ou scientifique) n'effectue que 12 heures d'enseignement (au lieu de 22 pour son cadre) afin de pouvoir se consacrer à la recherche des documents et à la préparation des fiches pédagogiques.

En matière scientifique l'introduction du concret est systématique, et les applications, les vérifications expérimentales sont multipliées le plus possible. Les mathématiques peuvent utiliser les résultats obtenus au cours d'essais pour dégager les théorèmes - ou encore proposer, aux divisions voisines, des exercices pratiques.

C'est ainsi que nous avons pensé installer plusieurs pluviomètres de taille et de forme différentes (en batteries). La lecture des colonnes d'eau obtenues montre que :

- a) le volume recueilli est proportionnel à la surface de réception,
- b) le volume recueilli ne dépend pas du type de surface,
- c) les erreurs sont d'autant plus faibles que les chiffres sont plus grands.

Un emploi du temps fixe et traditionnel (découpé en cours de 55 minutes chacun) a été maintenu afin de ne pas trop désorienter le maître et de lui permettre de garder la notion de durée, afin aussi d'habituer les élèves au cadre de travail auquel ils seront soumis ultérieurement. Cependant chaque maître a toute latitude d'opérer des assouplissements dans la répartition théorique. Ce qui lui permet de poursuivre et d'achever l'exposé d'un chapitre plus long et plus difficile. Des glissements inverses seront effectués au profit des matières provisoirement délaissées. Cette souplesse d'application doit assurer une efficacité plus grande, sans réduire ou diminuer le programme tracé à l'avance.

Le plus difficile a été pour nous de prévoir la répartition hebdomadaire du travail et de dégager les principales articulations du programme afin de maintenir une coordination directe entre les différentes spécialités. Nous donnerons, à ce propos, 3 exemples de notre grille pédagogique actuelle en ce qui concerne l'enseignement scientifique :

1)- 2ème Semaine -

Sciences Naturelles :

Morphologie humaine : mensurations des élèves - taille, envergure - coefficient thoracique - longueur des membres - poids etc. - établissement d'une fiche anthropométrique individuelle - recherche des rapports - construction d'un graphique.

Géographie :

Orientation - les points cardinaux - le globe terrestre - la carte - la boussole - Utilisation.

Mathématiques :

Longueur définie comme distance de 2 points - Mesures - Instruments de mesure.

Initiation technologique :

Mesures des longueurs (micromètre, pied à coulisse).

2)- 6ème Semaine -

Sciences naturelles :

Circulation du sang - Rythme cardiaque - Variations - (exercices pratiques et conclusions générales).

Géographie :

Débit et régime des fleuves - Le Nil, le Mississipi - l'Ikopa, le Mangoky.

Mathématiques :

Mesure de capacités - Unités.

Initiation technologique :

Mesure des capacités - Propriétés des fluides - (Discussion et application en liaison avec les Mathématiques).

3)- 11ème Semaine -

Sciences naturelles :

Les principales roches - Sable, calcaire, granit, basalte - (Etude pratique des caractères).

Géographie :

Aspects du relief en liaison avec les roches. Interprétation de documents photographiques.

Mathématiques :

Pente - Calcul - (applications numériques).

Initiation technologique :

Courbes de relief (maquette d'un relief) - Utilisation des connaissances acquises lors de la 2ème semaine avec extension à la 3ème dimension - Cas des droites non parallèles - Notation et cotation de pente.

Le calendrier des travaux et le contenu des leçons correspondent exactement aux programmes de l'enseignement court et long en vigueur dans la classe de 6ème :

- d'une manière stricte pour les mathématiques ;
- d'une manière souple pour la géographie et les sciences naturelles. [...]

Les éléments de technologie, qui sont en réalité des travaux scientifiques appliqués, représentent le domaine le plus délicat car il n'existe, à notre connaissance, aucune tentative d'initiation à la technologie au niveau de la classe de 6ème. C'est dans l'élaboration des chapitres et des articulations de cette matière que notre mise au point est la plus imparfaite. Un gros effort sera fourni dès la 2ème année d'essai.

Chaque fois que cela était possible, nous avons dédoublé la classe en deux groupes (géographie, sciences naturelles, exercices de mathématiques, technologie) afin de faciliter le contact avec les élèves et d'augmenter la participation individuelle dans le dialogue avec le maître. Les résultats sont encourageants et le niveau du français parlé s'est bien amélioré depuis le début de l'année scolaire.

En ce qui concerne les interrogations et le contrôle du travail, nous avons instauré le régime du test d'application où la part de réflexion est grande. Ils peuvent être hebdomadaires ou mensuels. A la fin de chaque trimestre, un exercice général permet de suivre les progrès et de vérifier les acquisitions de la période en cours. Enfin, au terme de l'année scolaire (Juillet 1968), un examen sera proposé aux élèves permettant de tester leur niveau général. Il serait bon aussi de vérifier l'état des connaissances en début d'année scolaire, à la rentrée en 6ème pour mesurer les progrès accomplis en cours d'année.

On pourrait de même faire subir un dernier contrôle aux élèves sortant de cette 6ème, après les vacances scolaires au moment de leur passage en 5ème.

LES RESULTATS EN COURS

Afin de ne pas perdre le contact avec les classes traditionnelles, nous avons opéré une épreuve commune (à la fin du 2ème trimestre). Nous avons choisi 2 classes de 6ème de lycée et une classe de Collège d'enseignement général comme classe de référence.

Les résultats chiffrés montrent en premier lieu que tous les tests étaient intéressants et de niveau, sauf celui d'histoire dont les résultats sont inégaux et celui de mathématiques jugé difficile. Dans l'ensemble, nous pouvons dire que les résultats sont satisfaisants. Nous obtenons une moyenne générale de 11,26, ce qui suppose que l'acquis de nos élèves est suffisant. Dans les diverses matières nous approchons toujours de la meilleure moyenne obtenue dans un lycée avec des élèves théoriquement supérieurs et des professeurs spécialisés. Nous sommes même les mieux placés en mathématiques et en sciences naturelles. [...]

LES CONCLUSIONS

D'ores et déjà nous pouvons dire que l'expérience en cours est intéressante par les résultats qu'elle permet d'espérer (avec toutes les réserves que cela comporte) et par les enseignements qu'elle nous a apportés. Le travail ne fait que commencer et nous espérons pouvoir dominer la plupart des problèmes en suspens avec le temps et les moyens mis à notre disposition.

Il serait souhaitable à l'avenir,

- dans un premier temps :

- 1) de reconduire la même expérience avec les mêmes maîtres,
- 2) de confier celle-ci, en outre, à d'autres enseignants avertis, français ou malgaches, de formations diverses,
- 3) de choisir et de multiplier les conditions pour en éprouver l'efficacité : à la ville et à la campagne, dans des établissements spécialisés (O.N.) ou normaux (C.E.G.), à l'Est, au Centre, à l'Ouest de Madagascar.

Les applications peuvent facilement être réalisées et contrôlées à condition de prévoir un décalage dans l'exécution pour assurer l'impression et l'acheminement des fiches mises au point dans l'établissement pilote.

- dans un deuxième temps :

- 1) de prévoir l'élaboration d'une documentation (iconographique entre autres),
- 2) de préparer le matériel nécessaire à l'application des fiches de travail,
- 3) d'orienter la formation des maîtres responsables de l'enseignement de la 6ème, soit au niveau de l'Ecole Normale, soit au niveau de l'I.N.S.R.F.P.,
- 4) d'implanter et de diffuser cette méthode de travail avec prudence, dans les seuls centres où les garanties d'essai sont assurées, la généralisation du système n'intervenant qu'ultérieurement après le rodage progressif.

Il semble bon que nous puissions mener à bien notre entreprise car nous disposons à Madagascar de bonnes conditions de travail et d'un climat favorable aux réformes. [...]

Una experiencia de enseñanza integrada

Y. Cabanis

(Resumen)

El autor relata la experiencia de enseñanza integrada (en vez de por disciplinas separadas) que se efectúa desde octubre de 1967 en una clase de sexto curso de un colegio de enseñanza general de Tananarive. La enseñanza está distribuida entre cuatro profesores (disciplinas literarias, incluido el francés ; disciplinas científicas y tecnológicas ; inglés ; malgache). El horario está repartido en 27 horas semanales para una clase poco numerosa.

En los seis párrafos siguientes se indican las ventajas de la enseñanza integrada por oposición a los inconvenientes de la enseñanza tradicional distribuida en disciplinas separadas :

1) se facilita la transición entre la enseñanza primaria y la secundaria, lo que siempre es delicado.

2) el horario, mejor coordinado, está menos recargado ;

3) el desarrollo de la personalidad del niño y su formación general son más eficaces ;

4) los programas pueden coordinarse, con lo que se evitan repeticiones o errores en la distribución de las materias enseñadas ;

5) la utilización de los métodos pedagógicos modernos es más fácil ;

6) el acceso a la información mediante el estudio de un tema y el descubrimiento personal son facilitados.

Se dan ejemplos de programas y se formulan sugerencias para la continuación de tales experimentos.

One experiment in integrated education

Y. Cabanis

(Summary)

The author describes an experiment in integrated education (i.e. not divided up into separate disciplines) which has been taking place since October 1967 in the first year of a Collège d'Enseignement Général in Tananarive. The subjects are allocated among four teachers (literature, including French ; science and technology ; English ; and Malagasy). The weekly time-table is 27 hours, the class containing only a small number of pupils.

The arguments in favour of integrated education are set out in six paragraphs, which emphasise the disadvantages of traditional teaching methods by separate disciplines as opposed to the advantages of the new system :

- 1) the transition from primary to secondary education, which is always a problem, is made easier;
- 2) improved coordination reduces the hours of work ;
- 3) better provision is made for the development of the child's personality and his general education ;
- 4) programmes can be coordinated, thus avoiding repetition or mistakes in drawing up time-tables ;
- 5) modern teaching methods are easier to use ;
- 6) the approach adopted makes it easier for the pupil to accede to information and rediscover natural laws for himself.

Examples of programmes are given, and suggestions made for continuing experiments of this kind.

DOCUMENTATION SUR LES ASSOCIATIONS, INSTITUTIONS OU
PUBLICATIONS S'INTERESSANT A LA PEDAGOGIE EN BIOLOGIE
DOCUMENTATION ON ASSOCIATIONS, INSTITUTIONS OR PUBLI-
CATIONS CONCERNED WITH THE TEACHING OF BIOLOGY

1. ASSOCIATIONS INTERNATIONALES/
INTERNATIONAL ASSOCIATIONS

a) Répertoires généraux/General directories

- Répertoires internationaux del'UNESCO sur les associa-
tions d'enseignants.
UNESCO, 1961.
- The Year Book of the International Council of Scientific
Unions.
ICSU Secretariat, 7, Via Cornelio Celso, 00161, ROME.

b) Associations

- Asian Association for Biology Education (AABE).
Science Education Center, University of the Philippines
Benitez Hall, Diliman, QUEZON City.
- Association Européenne des Enseignants,
18, rue d'Enghien, PARIS 10°, France.
- Fédération des Enseignants d'Afrique Noire,
B.P. 307, CONAKRY, République de GUINEE.
- International Federation of Secondary Teachers,
Yerdon House, 29, Gordon Square, LONDON WC1, G. B.
- New Education Fellowship,
1, Park Crescent, LONDON WC1, G. B.
- Secrétariat Professionnel International de l'Enseignement,
Place Fontainas 9-11, BRUXELLES 2, Belgique.
- World Confederation of Organizations of the teaching pro-
fession,
1227 Sixteenth Street, N.W., WASHINGTON, DC, USA.

2. DOCUMENTATION PAR PAYS/DOCUMENTATION BY COUNTRY

Cette documentation, très inégale, ne concerne que quelques pays pour lesquels des indications ont pu parvenir en temps utile à l'Editeur (Prof. R. HELLER, 1, rue Victor-Cousin, PARIS 5^e): il est vivement souhaité pour les prochaines éditions que des données analogues soient fournies sur les autres pays.

BELGIQUE/BELBIUM/BELGICA

- Association Nationale des Professeurs de Biologie de Belgique
147, Avenue Paul Deschanel, BRUXELLES.

DANEMARK/DENMARK/DINAMARCA

- Foreningen af Gymnasiets og Seminariets Laerere i Geografi of Naturhistorie
Juliusveg 6, GENTOFFE.
- Naturhistorie og Geografi Laerere Foreningen
Abakkeveg 54, KØBENHAVN F.

ETATS-UNIS D'AMERIQUE/UNITED STATES OF AMERICA/ESTADOS UNIDOS DE AMERICA

a) Associations

- National Association of Biology Teachers
Indiana University, BLOOMINGTON.

b) Institutions diverses

- American Institute of Biological Sciences
Journal : BioScience, mensuel
3900 Wisconsin Av., N.Y., WASHINGTON, D.C. 20016.
- Biological Sciences (BSCS)
Nombreux ouvrages et publications, notamment :
 - Edition des BSCS International News Notes
 - Edition des BSCS Newsletter.Univ. of Colorado, P.O. Box 930, BOULDER, 80302.

c) Ouvrages généraux

- Biology as inquiry, A book of teaching methods.
by VOSS and BROWN, The G.V. Mosby Company Ed.,
Saint-Louis, 1968, 239 p.
- Sixth Report of the International Clearinghouse on Science and Mathematics Curricular Developments.
J.D. LOCKARD Ed., Amer. Ass. for the Adv. of Sc.,
Univ. of Maryland, 1968, 441 p.

FRANCE/FRANCIA

a) Associations

- Associations des Professeurs de Biologie et Géologie de l'Enseignement public (ancienne Union des Naturalistes)
29, rue d'Ulm, PARIS 5°.

b) Publications

- Bulletin de l'A.P.B.G. (voir ci-dessus) , trimestriel, publiant fréquemment des résultats d'expériences pédagogiques et des références bibliographiques.
- L'Information scientifique (Baillière édit.)
19, rue Hautefeuille, PARIS 6°.
- L'Education Nationale et Documents pour la classe
Abonnement au S.E.V.P.E.N.
13, rue du Four, PARIS 6°.
- Centre Audio-Visuel (C.A.V.), documents et matériel audio-visuel
2, Avenue du Palais, Ecole Normale Supérieure,
92-SAINT-CLOUD.
- Cinémathèque, Service du Film de Recherche Scientifique ,
Nombreux films scientifiques ou scolaires . Catalogue sur demande.
Office National des Universités et Ecoles Françaises
96, Boulevard Raspail, PARIS 6°.

KENYA

- Bulletin du Centre régional de science et de technologie pour l'Afrique. B. of Regional Center of Science and Technology for Africa
Edité par l'UNESCO. Existe en français et en anglais.
trimestriel. Contient des articles divers qui sont souvent susceptibles d'intéresser les Biologistes.
Dr. A. Gille, Box 30592, NAIROBI.

JAPON/JAPAN/JAPON

- Nihon Seibutsu Kyoiku-Kai
Nihon University, Buzan High School
18 Otsuka-Sakashita-cho, Bunkyo-ku, TOKIO.

PAYS -BAS/NETHERLANDS/PAISES BAJOS

a) Associations

- Velebi (vereniging van leraren in de biologie)/Association de professeurs de biologie)

Secrétaire : Dr. S. R. Van Asperen de Boer
Gerrit van der Veenstraat 15 , AMSTERDAM.

b) Institutions diverses

- Onderwijscommissie van de Biologische Raad (Commission d'enseignement du Conseil Biologique qui constitue une section de l'Académie Royale des Sciences)

Secrétaire : M. G. P. Hekstra
Kloveniersburgwal 29, AMSTERDAM.

c) Centres d'études pédagogiques

formant un trait d'union entre les professeurs et le Ministère, ils stimulent les recherches pratiques concernant l'enseignement :

- C.P.S. (Christelijk Pedagogisch Studiecentrum/Centre d'études pédagogiques chrétiennes)

Secrétaire : Laan Van N. O.
259, Indië, DEN HAAG.

- O.S.C. (Onderwijskundig Studie Centrum/Centre d'études de l'enseignement).

Secrétariat : Orange Nassaulaan 51, AMSTERDAM.

d) Professeurs de méthodologie de la Biologie des Facultés des Sciences de chaque Université :

- Université Libre d'Amsterdam

Dr. M. A. Ljsseling
Rozenhof 7, ZUTPHEN.

- Université Catholique de Nimègue

M. F. Van Oostrum
Parkweg 62, NIJMEGEN.

- Universités d'Etat d'Utrecht et de Leyde)

Dr. J. C. Van der Steen
Marislaan 28, UTRECHT.

- Université d'Etat de Groningue

M. A. J. Treffers
Vosbergerlaan 35, EELDE.

- Université Municipale d'Amsterdam

Dr. P. Vermeulen
Wodanstraat 14, AMSTERDAM.

REPUBLIQUE FEDERALE D'ALLEMAGNE/FEDERAL REPUBLIC
OF GERMANY/REPUBLICA FEDERAL DE ALEMANIA

a) Associations

- Verband Deutscher Biologen (VDB) e.V.
Vorsitzender : Prof.Dr. F. Schaller
Geschäftsführer : Oberstudienrat G. Grasse,
Iserlohn, Baarstr. 38
Schulausub : Prof.Dr.F. Seidel,Marburg/Lahn
- Gesellschaft Deutscher Naturforscher und Ärzte
"Arbeitsgemeinschaft Deutscher Höhere Schule"
- Deutscher Verein zur Förderung des mathematischen und naturwissenschaftlichen Unterrichts
Vorsitzender : Prof.Dr. Frantz Mutscheller,Karlsruhe
- Bayerischer Philologenverband, Landesfachgruppe Biologie
Vorsitzender : Oberstudiendirektor Dr. Spanner
8031 Gröbenzell, Puchheimerstrabe 19.
- Institut für die Pädagogik der Naturwissenschaften an der Christian-Albrechts-Universität Kiel.

b) Publications

- Naturwissenschaftliche Rundschau, Stuttgart,
(mit spezieller Beilage des Verbandes Deutscher Biologen).
- Die Naturwissenschaften, Springer/Verlag/Heidelberg.
- Kosmos, Stuttgart (speziell für Lehrer an Höheren Schulen gedacht).

ROYAUME-UNI/UNITED KINGDOM/REINO UNIDO

a) Associations ou Institutions pédagogiques

- Association for science education

The association aims to improve the teaching of science in schools by providing facilities for the exchange of ideas between teachers in schools, universities and colleges of higher education. The Association's principle publication is the school Science Review which contains much valuable information on new experiments, improvised apparatus, laboratory design, articles reviewing new trends in science and book reviews. All teachers are eligible for election to membership.

General Secretary : Association for Science Education
52 Bateman Street, CAMBRIDGE.

- The Biological Council

The Biological Council was formed in 1945 to enable representatives of Societies and Associations in the biological sciences to meet periodically to discuss common problems and draw on each other's experience. It was soon realised that another body was required to deal specifically with the professional interests of biologists and it was largely on the initiative of the Council that the Institute of Biology was founded in 1950. Since then the Council has continued to meet twice yearly to deal with the more academic problems of the Societies that are now affiliated to it and where required to advise the Institute of Biology on such matters.

(Correspondence for the Biological Council should be sent c/o Institute of Biology, the address of which are given below).

Chairman : M.J. Way, Imperial College Field Station,
Silwood Park, Sunninghill, Ascot, Berks.

Hon. Secretary : Professor P.N. Campbell, Department
of Biochemistry, University of Leeds, 9 Hyde Terrace, Leeds 2.

Hon. Treasurer: P.A. Young, Wellcome Research Laboratories, Langley Court, Beckenham, Kent.

- Institute of Biology

Formed in 1950 to advance the knowledge of biology and to promote the professional standing, efficiency and usefulness of biologists. A symposium on a topic of wide interest amongst biologists is held annually, and there are other meetings on such subjects as the training of biologists, on the use of films in teaching or the design of biological laboratories.

The main publication of the Institute is the quarterly journal. Other publications include the Directory of Independent Consultant, Biology as a Career, and the annual Symposium.

General Secretary : D.J.B. Copp, B.Sc.,
41, Queen's Gate, LONDON S.W.7.

b) Sociétés scientifiques

- Association for the Study of Animal behaviour

Secretary : Dr. Janet Kear,
Wildfowl Trust, Slimbridge, GLOUCESTER.
• Journal - Animal Behaviour £ 5 per annum.

- British Society for Cell Biology

- British Ecological Society

Secretary : Dr. E.A.G. Duffey,
The Nature Conservancy, Marks Wood Experimental
Station, Abbot's Ripton, JUNTS.
Journals : 1. J. of Ecology £ 6.10 per annum,
2. J. of Annual Ecology £ 6.6s. per annum,
3. J. of Applied Ecology £ 6 per annum.

- The Centre for Educational Television Overseas

Secretary : Mr. J.W.R. Fox
The Studio, Nuffield Lodge, Regent sPark, LONDON, NW1

A non-commercial organisation established in 1962 to help advance the education of children and adults in developing countries by means of television. It offers advice and training in the use of educational television to any developing country.

- The Centre for Curriculum Renewal and Educational Development Overseas

Tavistock House South, Tavistock Square, LONDON, WC1

A non-commercial organisation which gives advice and assistance to schools in developing countries who are interested in the Nuffield Biology Teaching Project.

- Freshwater Biological Association

Secretary+Director : M.C. Gilson, Esq., M.A.,
The Ferry House, For Surrey, AMBLESIDE, Westmorland

- Marine Biological Association of the United Kingdom

The Director, The Laboratory, Citadel Hill, PLYMOUTH.
Journal of the Marine Biological Association of the U.K.
£ 11. per annum.

- The Royal Entomological Society of London

Secretary : Dr. D.R. Ragge

Journals : 1. Transactions of the Royal Entomological
Society of London. £ 10.10 s. per annum.
2. Proceedings of the Royal Entomological
Society. Series A - £ 4 per annum, Series
B - £ 4 per annum, Series C - £ 1-4 per annum.

- The Royal Microscopical Society

Secretary : Dr. S. Bradbury
Tavistock House South, Tavistock Square, LONDON WC1

Journals : 1. J. of Royal Microscopical Society, £ 15
per annum.
2. Proceedings of the Royal Microscopical
Society, £ 4 per annum.

- Society of Experimental Biology

Secretaries : Dr. M.A. Sleigh,
Department of Zoology, Univ. of Bristol,
and Dr. B.C. Loughman,
Department of Agriculture, Parks Road,
Oxford.

Journals : 1. J. of Experimental Biology, £6 per annum,
2. J. of Experimental Botany, £4.10 p.a.
3. J. of Cell Science, £8 p.a.
4. New Phytologist, £4 p.a.

- Society for General Microbiology, General Secretary.

Journal : J. of General Microbiology, £5 per annum.
Associations for educational development.

c) Ouvrages généraux

- Changing the Curriculum, edited by John F. Kerr, University of London Press LTD, St Paul's House, Warwick Lane, London EC 4, 1968, 112 p.

SUEDE/SWEDEN/SUECIA

- Biologilärarnas förening, Fatbursgatan 18 A, Stockholm SO.

TCHECOSLOVAQUIE/CZECHOSLOVAKIA/CHECOSLOVAQUIA

a) Institutions pédagogiques

- Pedagogical centres for methods and materials in Biology teaching (but not dealing exclusively only with biology) .
- Výzkumný ústav pedagogický (Pedagogical Research Institute).
Praha 1, Mikulandská 5.
- Ústavy učitelského vzdělání při pedagogických fakultách university Karlovy v Praze a university Komenského v Bratislavě (Institutes for the Education of Teachers at Pedagogical Faculty of Charles University in Prague and at Pedagogical Faculty of Komensky's University in Bratislava).
- Učební pomůcky (Teaching Materials), Praha 1, Staroměstské nám. 25.
- Stálá výstava učebních pomůcek (Permanent Exhibition of Teaching materials).
Praha 1, Národní třída 20.
- Vědecké filmy z biologie (Scientific films in Biology).
Czechoslovak Scientific Film Association, Brno, Botanická 8.

b) Publications

- Přírodní vědy ve škole (Natural Sciences in the School).

State Pedagogical Publishing House, Praha 2, Lazarská 8.

- Vysoká škola (High school = University).

State Pedagogical Publishing House, Praha 1, Valdštejnské nám. 1.



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